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APPLICATION GUIDE FOR THERMAL DESORPTION SYSTEMS

by

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13. ABSTRACT *(Maximum 200 words)*

This guide is intended to provide the Remediation Project Manager with guidance on implementing the use of thermal desorption systems at remedial action sites. The technology is referred to as either Low Temperature Thermal Desorption or High Temperature Thermal Desorption, depending on the treatment temperature achieved, although the breakpoint between the two is not well defined.

The Application Guide presents a brief overview of various thermal desorption systems currently popular in the industry, their applicability to various types of contaminants and a summary of the design and performance characteristics that might be expected. In addition, typical unit rate treatment costs for these systems are provided along with guidelines for estimating project costs, and a description of various contracting strategies and considerations.

The utilization of thermal desorption involves its compliance with various State and Federal regulations, and many of these are summarized in the Application Guide. Nonetheless, the acceptance of thermal desorption as a viable treatment technology, as an alternative to incineration, is typically made on a project-by-project basis.

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EXECUTIVE SUMMARY

Systematic guidance information on various currently available thermal desorption systems is not readily available. The purpose of this Application Guide is to provide (1) technical information on, design and performance characteristics, cost, associated regulatory compliance issues, and contracting strategies for deploying thermal desorption systems, and (2) to establish a process for implementing thermal desorption technology at naval installations. This guide is written primarily for technical personnel at naval engineering field divisions, public work centers and field activities and assumes that thermal desorption will be implemented primarily through a contract for services with a vendor who specializes in the installation and operation of thermal desorption systems for clean-up projects. This guide is intended to assist Remedial Project Managers (RPMs) and Project Engineers (PEs), who manage and execute environmental remediation projects at military facilities, by giving them knowledge and tools necessary in considering thermal desorption technologies for their projects.

The frequently debated definition of thermal desorption technology is that it is a two-step thermally induced physical separation process. It consists of one, applying heat to a contaminated material to vaporize contaminants into a gas stream, that two, is treated to meet regulatory requirements prior to discharge. Though most thermal desorption systems are applied to petroleum-contaminated sites, some are capable of handling contaminants ranging from high-molecular-weight polycyclic aromatic hydrocarbons (PAHs) and pesticides to chlorinated hydrocarbons, such as polychlorinated biphenyls (PCBs). This treatment is accomplished by one of two types of thermal desorption. Low temperature thermal desorption systems heat contaminated material between 200 to 600°F while high temperature systems involve heating the material between 600 and 1,000°F. Different models of thermal desorption systems are available and thorough physical and chemical site investigations are required to select a system for a given application. Each system has unique design and performance characteristics that must be acknowledged prior to its implementation. As with every remediation technology, there are a number of significant factors to consider when estimating the cost to deploy a thermal desorption system. Yet, unlike some technologies, it is strongly recommended that remediation projects using thermal desorption technology be completed through turnkey contracting services. Many factors discussed in this guide outline why Navy ownership and leasing of thermal desorption systems is not recommended.

There are many hurdles that would confront an RPM during the Remedial Action Process of a thermal desorption project, only one of which is regulatory compliance. Though not as numerous as for incineration, there are a number of federal, state, and local regulatory compliance issues that govern the use of thermal desorption. However, helpful case studies of projects that have applied thermal desorption technology, at Naval Station Mayport Jacksonville, Florida and the American Thermostat Site of South Cairo, New York, have provided key lessons for executing a project successfully.

Section 1.0: INTRODUCTION

This Application Guide is organized into several sections which provide an overview of the thermal desorption technology and takes the reader through the steps involved in contracting for thermal desorption services. Specific topics covered in each section are as follows:

- **Section 1 – Introduction**: Describes the overall purpose of the document and presents the organization of the document.
- **Section 2 – Overview of Thermal Desorption Systems**: Describes the available types of thermal desorption systems and provides a list of potential vendors for each type.
- **Section 3 – Applicability of Thermal Desorption Systems**: Describes when to use the various types of systems and the information needed to make this decision.
- **Section 4 – Design and Performance Characteristics**: Provides a summary of the design and performance characteristics of various thermal desorption systems.
- **Section 5 – Cost Data**: Discusses how to implement thermal desorption, and summarizes the advantages and disadvantages of government ownership versus subcontracting. This section includes typical cost information, summarizes operation and maintenance issues, and shows how to estimate the cost of a project.
- **Section 6 – Contracting Strategies**: Provides a summary of the contracting options available to implement thermal desorption.
- **Section 7 – Regulatory Compliance Issues**: Provides a general discussion of the types of regulations that may be applicable to thermal desorption remediation projects and lists current cleanup requirements by state.
- **Section 8 – Case Studies**: Provides a summary of two representative thermal desorption projects as case studies. One case study is a small project involving petroleum-contaminated soils, and the other is a large project involving soils contaminated with chlorinated organics.
- **Section 9 – Implementing a Thermal Desorption Project**: Briefly summarizes the initial steps of contracting a site for clean-up and restoration. Also notes key factors that RPMs should acknowledge when considering thermal desorption application.
- **Section 10 - Summary**

- **<u>Section 11 – References and Bibliography</u>**: Provides a list of relevant references used in the development of this Application Guide.

Additionally, a series of appendices provide supplemental information for implementing thermal desorption technologies on remediation projects.

- **Appendix A – Comparison of Direct-Contact Thermal Desorption to Incineration**: Compares selected design and operating parameters for direct-contact thermal desorbers and rotary kiln incinerators.

- **Appendix B – Contaminant Characteristics:** Presents characteristics of contaminants that affect the design and operation of thermal desorption systems.

- **Appendix C – Soil Characteristics:** Presents characteristics and properties of soils that affect the design and operation of thermal desorption systems.

- **Appendix D – Example Thermal Desorption HTRW Remedial Action Work Breakdown Structure:** Provides a representative work breakdown structure (WBS) for a thermal desorption project using the government's Hazardous, Toxic, Radioactive Waste (HTRW) WBS code of accounts.

- **Appendix E – Regulatory Cleanup Criteria:** Provides a reprint of a recent magazine article that summarizes petroleum cleanup standards for many states, and provides contacts for state environmental agencies.

- **Appendix F – Cost Factors:** Provides two tables describing factors that affect the cost to implement thermal desorption at a particular site.

- **Appendix G – Typical Project Tasks:** Provides a list of typical tasks that might be involved in a thermal desorption project.

- **Appendix H – Typical Thermal Desorption Specification:** Provides a standard specification for thermal desorption in Construction Specifications Institute (CSI) format.

- **Appendix I – Acronyms and Abbreviations Used in Application Guide Text and Appendices:** Spells out acronyms and abbreviations.

Section 2.0: OVERVIEW OF THERMAL DESORPTION SYSTEMS

2.1 U.S. EPA Definition of Thermal Desorption. Nominally, the United States Environmental Protection Agency (U.S. EPA) has recognized thermal desorption as a technology for more than 10 years, with it first having been designated as the remedial technology of choice in a Record of Decision (ROD) in 1985. A recent definition of thermal desorption was contained in the U.S. EPA Engineering Bulletin on Thermal Desorption Treatment (Superfund, EPA/540/S-94/501, February, 1994), which reads as follows:

> *"Thermal desorption is a process that uses either indirect or direct heat exchange to heat organic contaminants to a temperature high enough to volatilize and separate them from a contaminated solid medium. Air, combustion gas, or an inert gas is used as the transfer medium for the vaporized components. Thermal desorption systems are physical separation processes that transfer contaminants from one phase to another. They are not designed to provide high levels of organic destruction, although the higher temperatures of some systems will result in localized oxidation or pyrolysis. Thermal desorption is not incineration, since the destruction of organic contaminants is not the desired result. The bed temperatures achieved and residence times used by thermal desorption systems will volatilize selected contaminants, but usually not oxidize or destroy them. System performance is usually measured by the comparison of untreated solid contaminant levels with those of the processed solids. The contaminated medium is typically heated to 300 to 1,000 °F, based on the thermal desorption system selected."*

According to this definition, the U.S. EPA considers thermal desorption as *a physical separation process*, not as a form of incineration. However, some states may define certain types of thermal desorption systems as incineration and may require compliance with Resource Conservation and Recovery Act (RCRA) regulations. By defining the technology as thermal desorption, permitting requirements are not as severe and public opposition usually is significantly lower. Consequently, contaminated sites are being remediated. If the technology is classified as incineration, permitting becomes more difficult, operation becomes more expensive, and local public opposition becomes more vocal. The result is that projects are delayed and sometimes even canceled, which results in delays in cleaning up those sites. As a result, the definition of thermal desorption is sometimes controversial and continues to evolve.

Some regulators feel the U.S. EPA definition is unclear and enables projects to avoid complying with incineration requirements in cases where they should be imposed. The regulators are concerned that the potential for harm being caused to the public or the environment may be increased. As a result, the definition of thermal desorption is subject to interpretation and is applied inconsistently from state to state and project to project. The definition's own language states, "Volatiles in the off-gas may be burned in an afterburner…," which some technical people and state regulatory officials construe as incineration. In fact, examples exist of the very same thermal equipment being used in an incineration application on one project and then in a thermal desorption application on a subsequent one, with the only difference being the operating conditions used.

Despite the U.S. EPA's intentions, categorizing the various types of thermal treatment systems as to whether they are desorption systems or not has been difficult. In the context of this document, thermal desorption is commonly thought to entail heating the soil/sludge (or sediment) to about 300 to 600^{o}F (low temperature), where as applications involving the heating of soil/sludge to between 600 and 1,000^{o}F are considered to be high temperature thermal desorption.

Many of the Navy's remediation projects involve soils contaminated with benzene, toluene, ethylbenzene, and xylenes (BTEX) or total petroleum hydrocarbons (TPH). These compounds are easily and successfully treated using various types of proven thermal desorption systems. High-temperature incineration would be more costly and normally is not needed for these contaminants.

It is important to meet with concerned regulators (normally the state environmental agency) early in scoping a project where thermal treatment of any kind is to be used and to reach agreement on which regulations will apply, regardless of the name used to describe the treatment system.

2.2 Thermal Desorption Systems. A variety of thermal desorption systems are being used as part of numerous government and private remediation projects. All thermal desorption technologies consist of two steps: (1) heating the contaminated material to volatize the organic contaminants, and (2) treating the exhaust gas stream to prevent emissions of the volatized contaminants to the atmosphere. The systems are differentiated from each other by the methods used to transfer heat to the contaminated materials, and by the gas treatment system used to treat the off-gases. Heat can be applied directly by radiation from a combustion flame and/or by convection from direct contact with the combustion gases. Systems employing this type of heat transfer are referred to as *direct-contact* or *direct-fired* thermal desorption systems. Heat also can be applied indirectly by transferring the heat from the source (e.g., combustion or hot oil) through a physical barrier, such as a steel wall, that separates the heat source from the contaminated materials. Systems employing this type of heat transfer are referred to as *indirect-contact* or *indirect-fired* thermal desorption systems.

Thermal desorption systems can be further divided into two broad categories: continuous-feed and batch-feed types. Continuous-feed systems are ex situ processes, meaning that the contaminated material must be excavated from its original location, followed by some degree of material handling, and then fed to the treatment unit. Continuous-feed thermal desorption systems can use either direct-contact (direct-fired) equipment or indirect-contact (indirect-fired) equipment. The following are representative types of continuous-feed thermal desorption systems:

- Direct-contact thermal desorption – rotary dryer
- Indirect-contact thermal desorption – rotary dryer and thermal screw conveyor.

Batch-feed systems can be either ex situ or in situ, the latter meaning that the material is treated in place, without the need for and expense of excavating or dredging it before

treatment. As with all thermal desorption systems, the off-gases from in situ systems must be treated prior to discharge to the atmosphere. The following are representative types of batch-feed thermal desorption technologies:

- Ex situ – heated oven and hot-air vapor extraction (HAVE)
- In situ – thermal blanket, thermal well, and “enhanced” soil vapor extraction.

2.2.1 Continuous-Feed Systems – Direct Contact. Direct-contact thermal desorption systems have been developed in at least three stages over the years. Throughputs of as high as 160 tons/hr have been demonstrated.

The first-generation direct-contact thermal desorption systems employ, as principal process elements, a rotary dryer, a fabric filter baghouse, and an afterburner, in that sequence. These systems are very economical to purchase and operate, but are limited in that they are useful only for low-boiling-point (below about 500 to 600EF), nonchlorinated contaminants. The material is generally treated to 300 to 400°F. Figure 2-1 illustrates a typical system process schematic. Due to the location of the baghouse, the system is not capable of handling high-boiling-point organics as the high-molecular-weight compounds would condense and increase the pressure drop across the bags.

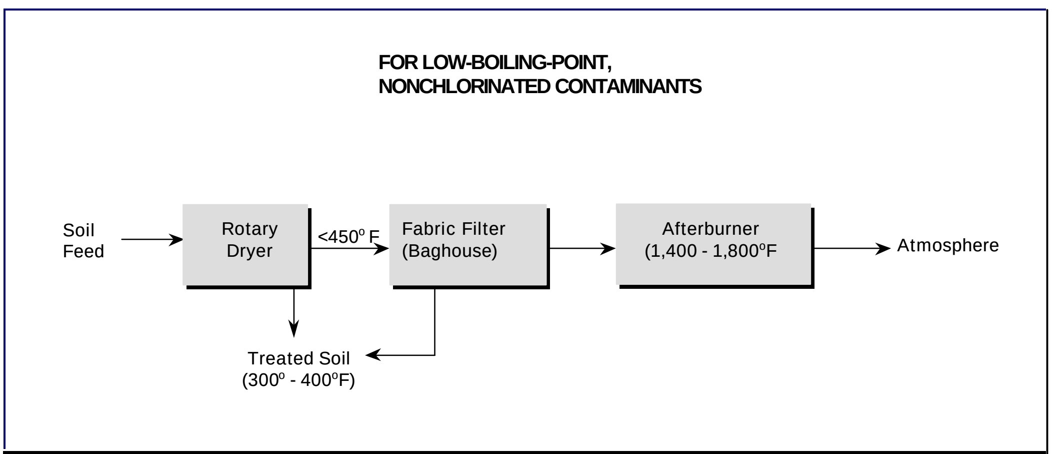


Figure 2-1. First Generation – Direct-Contact Thermal Desorption Process

The second generation of direct-contact thermal desorption systems was developed for higher-boiling-point, nonchlorinated contaminants (above 600°F). These systems usually employ a rotary dryer, an afterburner, a gas cooler, and a baghouse as the principal process elements, in that sequence. Figure 2-2 illustrates a typical system process schematic. This system can treat high-boiling-point organics because the dryer can heat the contaminated materials to higher temperatures without damaging the baghouse. Positioning the baghouse at the end of the treatment train enables it to remove particulates in the off-gas while maintaining temperatures in the gas stream in the 450 to 500°F range. In addition, vaporized organics are destroyed in the afterburner, thereby eliminating the potential for condensation of high-

molecular-weight organics in the baghouse. These thermal desorption systems are normally capable of heating the treated residue to a range of about 500 to 1,200°F. These systems can treat materials contaminated with heavier oils, but they are still limited to nonchlorinated compounds because they have no means of controlling the hydrochloric acid emissions resulting from the combustion of chlorinated compounds.

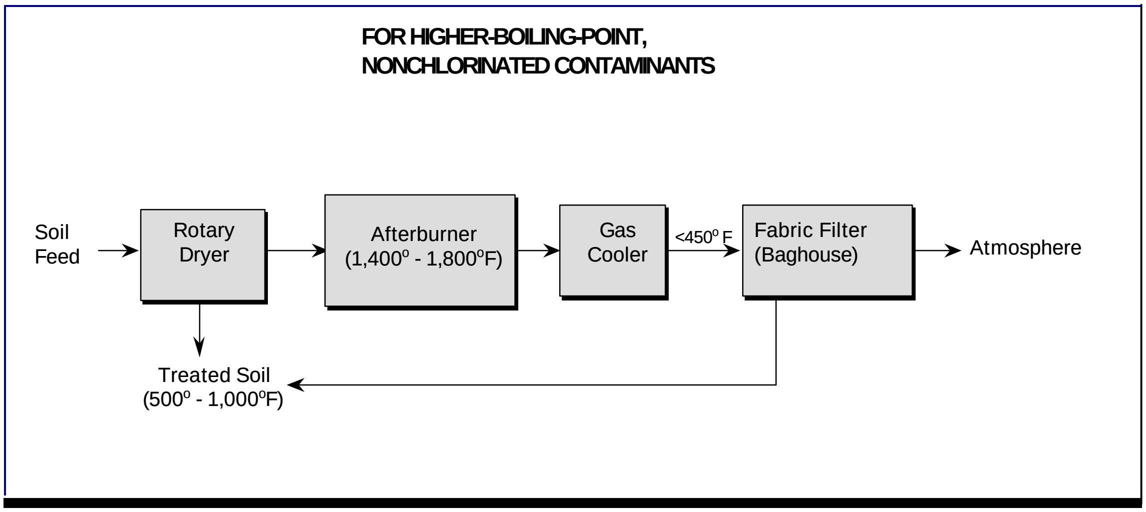


Figure 2-2. Second Generation – Direct-Contact Thermal Desorption Process

The third generation of direct-contact thermal desorption systems is intended for the treatment of high-boiling-point, chlorinated contaminants. Materials are usually heated to a range between 500 and 1,200°F in a rotary dryer and the off-gas subsequently is oxidized in an afterburner at temperatures in the range of 1,400 to 1,800°F, sometimes as high as 2,000°F. The off-gas is then cooled, or quenched, and passes through the baghouse as in a second-generation system. At the end of the treatment train, however, an acid gas neutralization system is included to control emissions of hydrochloric acid (HCl) to the atmosphere. A wet gas scrubber utilizing a caustic-enriched water spray is the most common acid gas control system used. Because the scrubber may be made of fiberglass-reinforced plastic (FRP) with a relatively low permissible operating temperature, an upstream quench stage (i.e., downstream of the baghouse) typically is used to cool the gas stream before it enters the scrubber. The addition of a wet gas scrubber increases the complexity to the thermal desorption system and the project because it involves water make-up, wastewater discharge flows, and monitoring and control of the water chemistry. In addition, some degree of particulate collection is achieved by the wet scrubber system. This particulate becomes sludge in the wastewater treatment system that must be removed and managed prior to discharge.

Figure 2-3 illustrates a typical system process schematic. This third-generation system is capable of handling and treating a very wide range of potential contaminants, including heavy oils and chlorinated compounds.

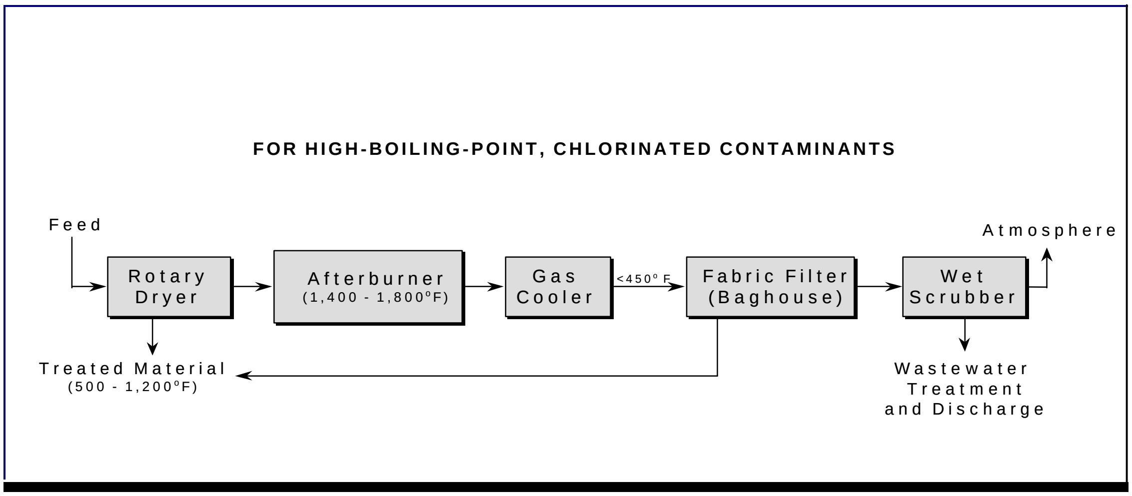


Figure 2-3. Third Generation – Direct-Contact Thermal Desorption Process

2.2.2 Continuous-Feed Systems – Indirect-Contact. Indirect-contact thermal desorption systems come in many types of designs. One such system uses a double-shell rotary dryer, with several burners mounted in the annular space between the two shells. The burners heat the exterior of the inner shell containing the waste as it rotates. Because neither the burner flame nor the burner combustion gas contacts the contaminated materials or off-gas evolving from the materials, the thermal desorption system is considered to use an "indirect" mode of heating. As a result, the burner combustion products can be directly discharged to the atmosphere, as long as a "clean" fuel is used such as natural gas or propane. As in the direct-contact type of rotary-dryer thermal desorber, the rotating action of the inner shell breaks up small clumps in the material, which enhances heat transfer and causes the soil to move laterally along the downward-sloped angle of the dryer assembly.

In the unit, process off-gas from the waste is limited to about 450°F, because it then passes through a baghouse upon leaving the rotary dryer.[1] The gas treatment system used in this system employs condensation and oil/water separation steps to remove the contaminants from the off-gas and residual streams. Therefore, the concentrated liquid contaminants removed from the system require further processing, either on site or off site, to achieve the necessary destruction into nonhazardous constituents. Figure 2-4 illustrates the process flow schematic for this process.

[1] This vendor is testing ceramic bags for the thermal desorption system baghouse which, if their performance is satisfactory, would allow for process off-gas temperatures up to 1,000°F and application of the unit to higher-boiling-point organics.

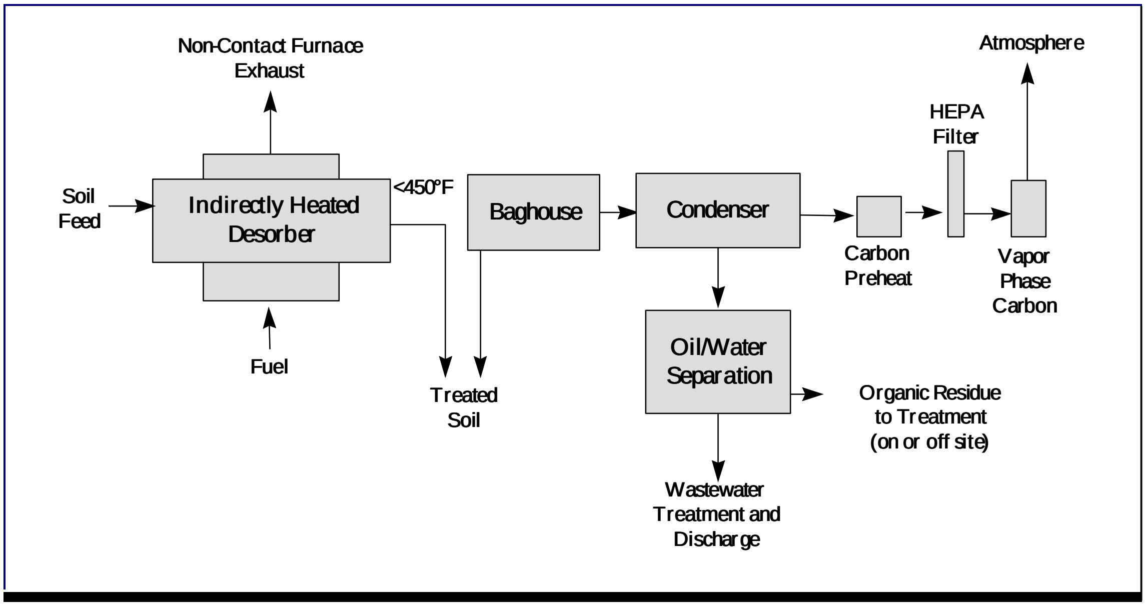


Figure 2-4. Indirect-Contact Rotary Dryer Thermal Desorption Process

This indirect-contact thermal desorption system seems to exemplify what the U.S. EPA intended in its definition of thermal desorption. In the first stage, contaminants are *desorbed;* i.e., they are separated from the material at a relatively low temperature. In the second stage they are condensed into a concentrated liquid form, suitable for transport off site to a fixed-base "traditional" treatment or disposal facility, such as a commercial incinerator. The contaminants are not destroyed via thermal oxidation in this type of thermal desorption system; instead they are separated from the bulk material for subsequent processing elsewhere. This type of thermal desorption process reduces the volume of contaminants that require further treatment.

The thermal screw conveyor is another type of indirect-contact thermal desorption system that has been used successfully other firms for smaller remediation projects. This design is also truly indirect contact, in that a heat transfer fluid, such as Dowtherm™ or oil, is heated separately from the thermal processing chamber in a small furnace, typically fueled by natural gas or propane. The hot oil is pumped to the thermal processing chamber, which is a covered trough (or series of covered troughs) mounted horizontally, with pairs of hollow-screw augers inside. The hot oil flows through the inside of these hollow screws and may also flow through an exterior jacket of the trough. The contaminated material is fed into the inlet end of the first-stage trough and, by the action of the rotating screws, moves to the outlet end where it falls into the second-stage trough situated below the first unit. The hot oil may flow counter-current to the material in the first-stage trough,and flow co-current in the second stage. The off-gas (steam and contaminants evolved from the material) leaves the troughs via a sweep gas (or steam) and can be either condensed to a concentrated liquid form or thermally oxidized. The system is compact and modular. Figure 2-5 illustrates the process flow schematic used.

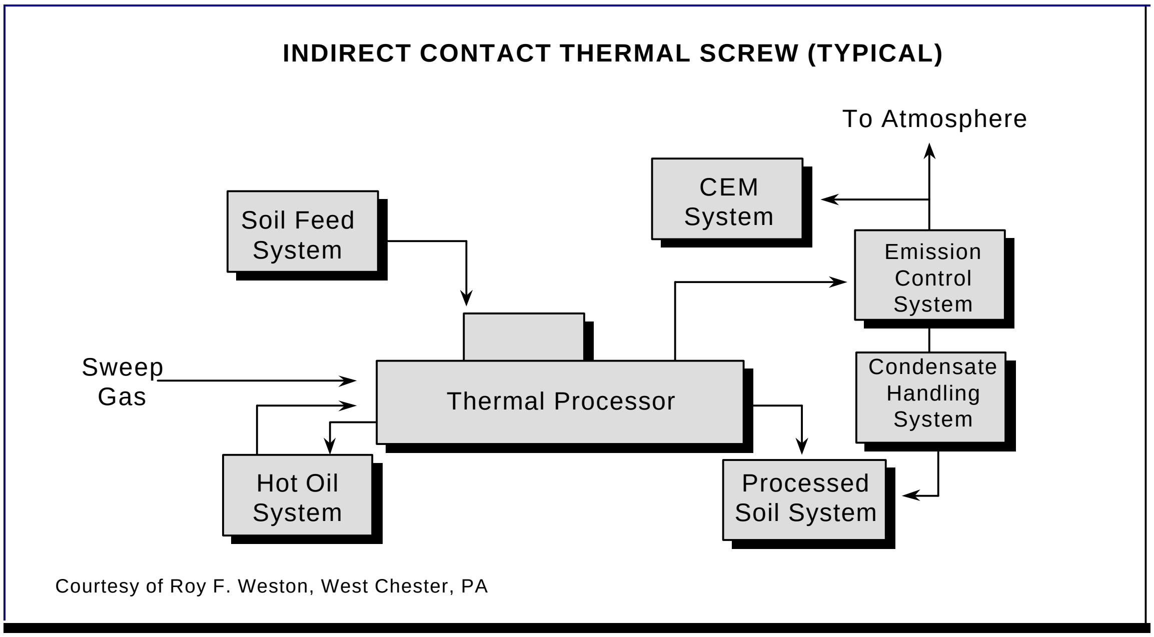
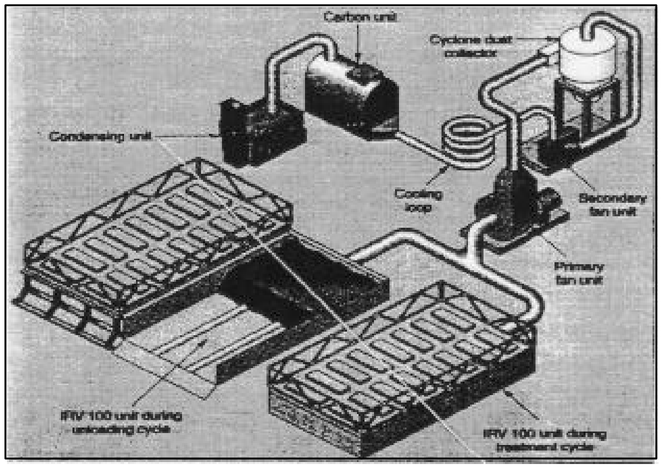


Figure 2-5. Indirect-Contact Thermal Screw Thermal Desorption Process

2.2.3 Batch-Feed Systems – Heated Oven. The heated oven thermal desorption system is a batch-type, ex situ design that has been improved in recent years. The desorption chamber is an "oven" where a small quantity of contaminated material, generally 5 to 20 cubic yards (CY), is heated for a given period of time, generally 1 to 4 hours. The number of chambers can be optimized to fit the project in terms of the total quantity of material to be treated, the timeframe to complete the project, the actual amount of time required per batch for the particular material and contaminant, the plot space available, and other variables. Normally, four or more chambers are used.

The heat source consists of aluminized steel tubes that are directly heated internally via propane to about 1,100°F. At this temperature, the tubes emit infrared heat externally as they radiate, which the vendor claims is more efficient than other means of heat transfer. Although the radiant energy heats only the top several inches of the 18-in.-deep bed of contaminated material, a downward flow of air is drawn through the bed by an induced-draft fan downstream of the treatment chamber. This creates a convective mode of heat transfer, which serves to strip the contaminants from the material. The treatment chamber operates at negative pressure. This system is illustrated in Figure 2-6.

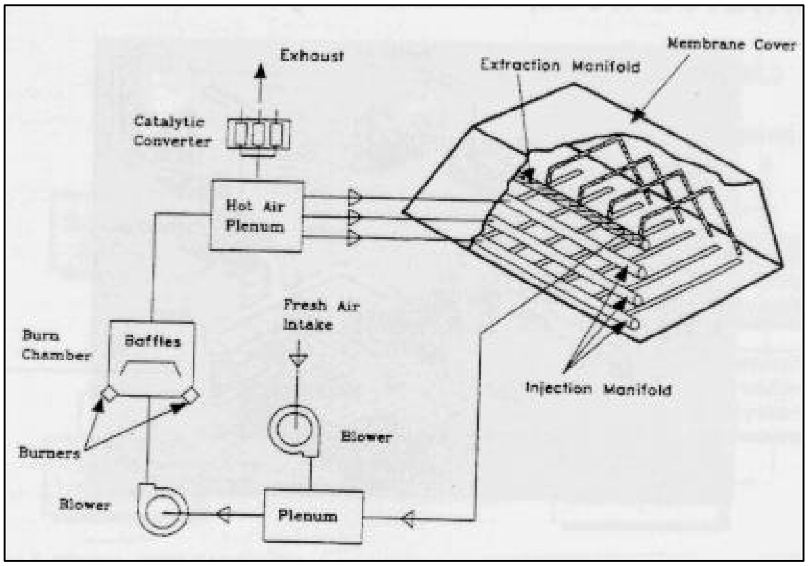


Courtesy of McLaren Hart, Warren, NJ

Figure 2-6. Batch-Feed Thermal Desorption System – Indirect-Contact Heated Oven

In recent years, the users have sought to adapt the system equipment to higher-boiling-point contaminants, such as PCBs, by modifying the design to maintain higher levels of vacuum. In doing so, the boiling point temperature of the contaminated medium is effectively reduced, because the operating pressure is maintained significantly below atmospheric pressure. A related improvement pertains to the seals for the treatment chamber. The original design employed a sliding cover that was moved laterally to allow access for loading and unloading the contaminated material by a front-end loader. The newer, higher-vacuum model has a smaller, tighter access door that is easier to seal, and the waste material is loaded and unloaded through a side door using a tray handled by a forklift. Although the heated-oven system has advantages in terms of simplicity, plot space, and setup time required, it is less widely used than some alternative thermal desorbers such as the rotary dryer, and it is best suited to smaller projects. Its throughput is relatively low and, because of the batch nature and small treatment chamber size, a significant amount of labor is expended in loading and unloading it.

2.2.4 Batch-Feed Systems – Hot-Air Vapor Extraction (HAVE) System. The HAVE thermal desorption system is an innovative cleanup technology that uses a combination of thermal, heap pile, and vapor extraction techniques to remove and destroy hydrocarbon contamination in material. This technology is effective in treating materials contaminated with gasoline, diesel fuel, heavy oils, and PAHs. The HAVE system has undergone a commercial-scale demonstration test by the Naval Facilities Engineering Service Center (NFESC) at Port Hueneme, California, using soils contaminated with diesel fuel and heavy oils. An NFESC technical report (TR-2066-ENV) that thoroughly describes the demonstration test, results and conclusions, and estimated cost information (Pal, et al., 1996). Figure 2-7 was taken from the report and illustrates the process schematic for the HAVE system.



Source: Technical Report TR-2066-ENV, Naval Facilities Engineering Service Center

Figure 2-7. Batch-Feed Thermal Desorption System—Direct-Contact HAVE System

As with most forms of thermal desorption, the HAVE system is an ex situ process. As the contaminated materials are excavated, they are placed in a pile of approximately 750 CY. The pile is built with pipe injection manifolds between various lifts of material as the manifolds are emplaced. An extraction manifold is placed at the top of the pile to collect volatized gases (steam and contaminants). The entire pile is covered with an impermeable cover to contain the vapors that will be produced, ensuring that they are captured by the extraction manifold.

External to the pile, a direct-contact burn chamber uses propane to heat the air that is circulated through the pile. As the material warms, the contaminants vaporize and are swept away by the air stream. As they pass into the burn chamber they become part of the combustion process and are oxidized, i.e., the contaminants are destroyed. They actually serve as a form of supplemental fuel in the burn chamber, helping to heat the circulating gas stream. To maintain combustion of the contaminants in the burn chamber, air is introduced into the circulation loop, replacing an equal amount of the exhaust gas exiting the burn chamber. This exhaust stream is vented to the atmosphere through a catalytic converter for treatment of any trace organics that may not have been oxidized in the burn chamber. At equilibrium conditions during the demonstration test, NFESC found that about 15% of the circulating gas volume needs to be bled off and replaced with fresh make-up air for combustion purposes.

Some of the conclusions drawn by NFESC as a result of the demonstration include the following:

- The HAVE technology was successful in remediating soils contaminated with gasoline, mixed fuel oils, and heavy fuel oils.

- The HAVE system performed well with soils containing less than 14% moisture and less than 20% clay.

- Materials can be heated to average temperatures in the range of 150^{o}F for gasoline contamination and up to approximately 450^{o}F for heavier fuels and oils.

- The "optimum" size pile was estimated to be approximately 750 CY. A pile this size, containing less than 20% clay, moisture of 12% or less, and TPH concentrations up to 5,000 mg/kg, can be remediated in about 18 days. Higher concentrations require longer treatment times.

Based on the above, it is estimated that the HAVE technology will be applicable to project sizes ranging from a few hundred cubic yards up to approximately 5,000 CY.

2.2.5 Batch-Feed Systems – In Situ Systems: Thermal Blanket and Thermal Well. The thermal blanket and thermal well types of thermal desorption technology are in situ thermal treatment technologies. At the present time they are proprietary technologies, and represent one of the few in situ forms of thermal desorption technology that have been demonstrated to work effectively on a commercial scale.

The thermal blanket system uses modularized electric heating "blankets" about 8 ft x 20 ft that are placed on top of the contaminated ground surface. The blankets can be heated to 1,000°C (1,832°F) and, by thermal conduction from direct contact with the contaminated material, are able to vaporize most contaminants down to about 3 ft deep. The blanket module is covered with an impermeable membrane having a vacuum-exhaust port. Several modules can be used simultaneously by connecting the exhaust ports to a common manifold leading to an induced-draft blower system. As the contaminants are volatized, they are drawn out of the contaminated material by the induced-draft blower. Once the contaminants are in the vapor stream, they are oxidized at high temperature in a thermal oxidizer near the treatment area. The gas stream is then cooled to protect the downstream induced-draft blower and passed through a carbon bed that collects any trace levels of organics not oxidized prior to release to the atmosphere.

The thermal well system involves an arrangement of electrical immersion heating elements placed deep in the ground at about 7 to 10 ft apart. The wells are intended to remediate contaminated material from about 3 ft below grade to at least the water-table elevation, if necessary. The heating elements are raised to more than 1,000°C to heat the surrounding material. Similar to the thermal blanket system, heat transfer for the thermal well system is via conduction only. The wells are installed with an outer perforated sleeve or screen. The top outlets of all of the wells used in a particular application are connected to a common manifold. Similar to the blanket modules, vacuum is drawn on the manifold to remove the desorbed contaminants from the material, evacuate them through the well sleeve/manifold network, and destroy them.

Vendor literature states that, in many applications, both the thermal blanket and the thermal well systems can be used sequentially to allow for effective remediation coverage from the ground surface down to at least the water-table level. The literature also states that thermal well technology is effective in remediating material below the water table, as long as a barrier is installed to prevent water infiltration to the well field area. If water flow were not restricted, system performance and efficiency would be reduced by the need to evaporate significant volumes of groundwater locally.

A vendor has successfully demonstrated their thermal blanket and thermal well technologies at a PCB-contaminated site in upstate New York. They have conducted another demonstration for the Navy as part of the Mare Island project for PCB remediation under the Bay Area Defense Conversion Action Team (BADCAT) Program in California. Information from this effort is available from NFESC.

The thermal blanket and thermal well systems both avoid the need to excavate contaminated material, thereby eliminating material handling concerns along with the cost of the excavation itself. The two systems can be thought of collectively as thermally enhanced soil vapor extraction (SVE). Therefore, as with SVE, the geotechnical characteristics (such as permeability) of the ground to be treated must be suitable for these technologies to be feasible. They are also quiet and less obtrusive than many other thermal desorption technologies. At the present time, however, their treatment costs are higher than costs for more established technologies (refer to Section 5.0). Their costs may become more competitive in the future as the technologies develop and become more popular.

2.2.6 Batch-Feed Systems – In Situ Systems: Enhanced Soil Vapor Extraction (SVE). Enhanced SVE uses a series of wells installed in the contaminated areas. One series of wells is used to inject hot air or steam into the ground to heat the materials and contaminants. A vacuum is applied to the rest of the wells to extract the volatized contaminants from the materials. The gases extracted from the wells can be treated in the same manner as with other thermal desorption technologies, i.e., through condensation, collection on activated carbon, or combustion.

Three factors control the effectiveness of enhanced SVE: (1) the physical and chemical properties of the contaminants to be removed, (2) the "in-place" air permeability of the materials to be treated, and (3) the homogeneity of the materials. Because this technology is well established and documented in various reports and design documents, it will not be addressed in any more detail here.

2.3 Generalized Process Flow Diagram. In their most generic form, ex situ thermal desorption processes can be represented schematically as shown in Figure 2-8. The diagram underscores the view that thermal desorption is a separation process during which organic contaminants (and sometimes inorganic contaminants, although this is not the intent) are separated from the waste feed material. The treated solids are essentially free of organic content, a fact that must be considered if the material is to be backfilled and revegetated. Because organic content is necessary to sustain vegetation, the treated residue must be amended with organic nurtients. Typically, however, treated residue will be backfilled and compacted to prevent erosion, then covered with 6 inches or so of clean topsoil to support grass growth.

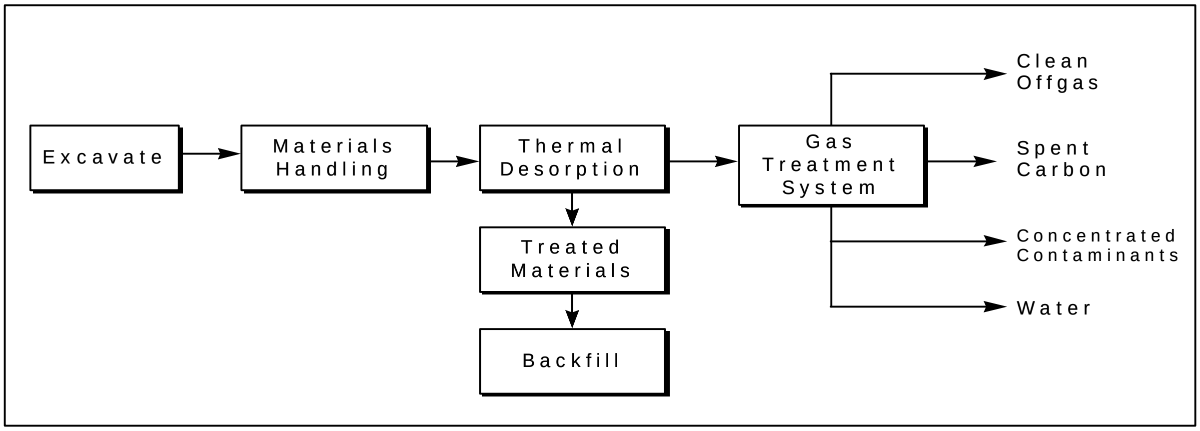


Figure 2.8. Generalized Schematic Diagram of Ex Situ Thermal Desorption Process

Also, although not indicated on the simplified schematic in Figure 2-8, materials treated by thermal desorption may require further treatment for inorganic fixation, if leachable levels are above those permitted to allow direct backfill. This need would be determined by the Toxicity Characteristic Leaching Procedure (TCLP) or other testing on a periodic basis.

The process off-gas leaving the thermal desorption step contains virtually all the organic contaminants included with the waste feed. The selection of the gas treatment system depends on the nature and concentrations of the gas-phase contaminants, permissible emission limits for those that are regulated, allowable particulate levels in the final discharge to the atmosphere, and cost considerations. The reader should be aware that particular state air quality standards often are more stringent than federal levels and the location where the project is to be performed must be considered. For example, federal law limits particulate emission levels to 0.08 gr/dscf whereas many states have a lower limit, such as 0.05 gr/dscf. Measured particulate levels generally are corrected to a stipulated oxygen content (such as 7% O_2) in the stack exhaust flow as the basis used to establish the regulatory limit, for a consistent comparison.

Regardless of the type of thermal desorption system employed, the degree to which thermal desorption of a given wastestream will be successful depends largely on the temperature to which it is heated, the geotechnical characteristics of the waste (i.e., it is easier to desorb contaminants from coarse-grained materials than from fine-grained materials such as silts and clays), the specific contaminants and their degree of affinity for the soil or sediment particles, and the amount of moisture. Thermal treatment systems are effective if adequate time, temperature, and turbulence are provided during processing.

The "time" refers to the residence time, which is related to the throughput. Throughputs are adjustable to suit the requirements of the system and situation. For example, for a rotary dryer system, residence times of between 5 to 60 minutes are common. The greater the residence time, the slower the throughput and the higher the unit treatment cost. Hence, there is motivation for optimizing residence time. For a rotary dryer, two operational variables that

control residence time are rotational speed and slope, while physical equipment dimensions and configuration of the internals are fixed factors that also affect it.

"Temperature" refers to the bulk temperature to which the waste matrix is heated. This is generally lower than the gas-phase temperature in a rotary dryer because heat is transferred from the burner combustion gas to the waste material. Counter-current flow patterns (i.e. the burner(s) is mounted opposite the waste feed end) are common because this heat transfer pattern is more efficient. The effectiveness of the treatment process depends primarily on the bulk temperature to which the waste is heated. In all types of thermal desorption units, however, fuel (i.e., natural gas, liquid propane gas, fuel oil, etc.) is used to heat the waste and, because the fuel cost is one of the dominant operational costs, "overheating" the waste can be expensive.

"Turbulence" is achieved by mixing and lifting the waste material to ensure that all the particles are heated as uniformly as practical. Turbulence reduces the possibility that some self-insulating clumps of waste may avoid being heated sufficiently to reach the necessary temperature to be desorbed. Design of the internals of a thermal desorption unit can be trial and error, as too much turbulence may result in particle carryover to the gas-phase cleaning and treatment system. Also, some high temperature thermal desorbers may require a refractory-lined interior to accommodate the higher temperatures, which further complicates the design and modification of internals intended to achieve adequate turbulence.

In addition to the operational considerations of time, temperature, and turbulence needed to attain effective thermal treatment, adequate and appropriate waste feed preparation is essential. Most wastestreams are nonhomogeneous with respect to contaminant concentration, moisture content, British thermal unit value, halogen concentration, particle size, chunks of debris, inorganics, and other factors that influence whether the thermal processing occurs efficiently and adequately. Large pieces of debris or boulders (typically greater than 2") should be removed in the pretreatment process. They can be either manually decontaminated (by steam or high-pressure water wash) or crushed and processed through the thermal desorption system gradually. The importance of sorting, mixing, and blending the waste feed in an attempt to "normalize" most of these variables cannot be overstated in terms of achieving reliable treatment feed results. Homogeneous waste fee will reduce the likelihood for mechanical problems that can greatly increase the project cost and/or required schedule time.

Section 3.0: APPLICABILITY OF THERMAL DESORPTION SYSTEMS

3.1 Site Characterization. Site characterization for a remediation project must be sufficiently thorough and accurate to reliably predict operational performance and estimate remediation costs. For these reasons, proper site characterization is necessary for projects the Navy may wish to execute itself, such as employing the HAVE system. It is perhaps even more critical when the Navy contracts thermal desorption services, because the likelihood for claims during project performance will be reduced.

The results of the site characterization are used to determine whether the contaminated soil is a RCRA hazardous waste, a Toxic Substances Control Act (TSCA)-regulated substance, or a nonregulated petroleum-contaminated material. The material may also be listed as a hazardous waste under individual state regulations. For example, virgin petroleum-contaminated soils with TPH concentrations above specified levels are listed as hazardous wastes in Massachusetts and New Jersey. This designation is significant because, if the material is a RCRA hazardous waste, a TSCA-regulated substance, or a state-listed hazardous waste, the use of thermal desorption in lieu of incineration may not be permissible according to the state regulatory agency. Alternatively, in some states a thermal desorption system may be utilized while complying with pertinent incinerator regulations.

Soils and sediments are inherently variable in their physical and chemical characteristics. These characteristics must be described accurately because each technology works best on a certain type of materials. Some important properties of waste materials, and the reasons for considering them, are presented in Sections 3.1.1 through 3.1.13.

3.1.1 Chemical Composition. In addition to analysis for metals (See Section 3.1.12), the range and concentration of organic contaminants must be determined to assess the viability of and necessary operating conditions for the thermal desorption process. Sulfur and nitrogen usually are included because they may result in the production of sulfur dioxides or nitrous oxides in the process off-gas. These pollutants may require further treatment.

3.1.2 Soil Particle Size Distribution. The breakpoint between coarse-grained material and fine-grained material is generally considered with respect to the percentage of particles greater or smaller than 200 sieve size (0.075 mm). If more than half the material is larger than 200 sieve size, it is considered coarse (i.e., gravel or sand). If more than half the material is smaller than 200 sieve size, it is considered fine, consisting of silts and clays. Fine-grained material may result in carryover in rotary dryer systems, meaning that it exits the dryer entrained in the gas stream instead of with the treated residue, which is preferred. The undesirable carryover can overload the downstream gas-handling and treatment equipment, causing pressure profile and buildup problems, and possibly exceeding the ability of the baghouse or cyclone and conveyor equipment to recover it and rejoin the fines with the treated residue.

3.1.3 Composition. Waste material composition refers to the amount of sand, clay, silt, rock, ect. that is present. For heat transfer and mechanical handling considerations, information on composition must be known. In general, coarse, unconsolidated materials

such as sands and fine gravels are more readily treated by thermal desorption because they tend not to agglomerate into larger particles and more of the surface area of the particles is exposed to the heating medium. Agglomerated (i.e., larger) particles are somewhat self-insulating, which may interfere with thorough heating and, hence, desorption of the contaminants. Large rocks create material-handling difficulties for conveyors and augers. The maximum particle feed size typically is limited to 2" for rotary dryer systems. Clays may cause poor thermal desorption performance by caking and inhibited heat transfer.

3.1.4 Bulk Density. Ex situ processes are concerned with bulk density as a conversion between tons and CY. When vendors determine operating costs, the actual weight of the material to be treated is more important than its volume to develop heat and mass balance relationships. However, volume may be preferred as the basis for payment because it can be measured in place accurately by survey, without consideration of whether a weigh scale was calibrated and without the need to subtract out the weight of feed material that may have been reprocessed and thus cross the feed scale twice.

3.1.5 Permeability. The property of permeability affects those processes involving the induction of vaporized contaminants through the soil media (such as the HAVE system and the in situ thermal desorption technologies). Clays and other tightly packed soils with very low permeabilities may not be suitable for treatment by these technologies.

3.1.6 Plasticity. The property of plasticity indicates the degree of soil deformation without shearing. Plastic soils, such as clays, tend to clump and form larger particles with low surface area to volume ratios, possibly resulting in inadequate heating of the interior core. They can also stick to and foul heat transfer surfaces, such as the exterior of a hot oil screw auger, decreasing thermal efficiency. Plastic soils may present material handling problems both before and during thermal desorption processing by sticking to and possibly jamming the equipment.

3.1.7 Soil In-Place Homogeneity. The characteristic of homogeneity is important with regard to in situ thermal desorption treatment with the thermal well and thermal blanket designs. Ideally, the subsurface should be nearly homogeneous, so that the underground vapor flow, heat transfer, and remediation are uniform. Large boulders, bedrock irregularities, sand lenses, or impermeable layers (such as clay) might adversely affect the consistency of the treatment process.

3.1.8 Moisture Content. Excess moisture can adversely affect operating costs when the moisture evaporates during treatment, requiring fuel. The added volume of water vapor in the process off-gas can result in lower waste throughput, because the water vapor must be handled by downstream treatment equipment along with off-gas and desorbed contaminants. The lower processing throughput is attributable to (1) higher gas flows, resulting in greater pressure drops through the thermal desorption system; and (2) thermal input limitations, because some of the heating input is used to vaporize the water in the waste feed, and the feed rate may need to be reduced to adequately heat the waste feed to achieve satisfactory desorption. For most rotary thermal desorption systems,

there is no significant effect on operational cost and/or throughput up to ~ 20% moisture content in the feed. Beyond 20% moisture content, it may be desirable to investigate whether the moisture content might be lowered more economically in the waste feed preparation process rather than in the thermal treatment process itself.

Some thermal desorption systems, such as the HAVE system, perform more effectively with a specific *minimum* amount of moisture in the feed material. This may be due to the enhanced heat transfer and thermal desorption of the contaminants resulting from the stripping action of the vaporized water (by steam). Additionally, some minimum amount of moisture is desirable in the waste feed to mitigate dusting problems during material-handling operations. Between 10 and 20% moisture content in the waste feed appears to be optimal.

3.1.9 Heat Content. Some thermal desorption units have a maximum thermal release they can accommodate, including that from the waste feed material. For contaminated soils or sediments of low concentration, this usually is not a concern because a relatively small heat release during thermal desorption is derived from the waste, and nearly all is obtained from the auxiliary fuel. However, soils with high concentrations of organics (above 1 to 3%) may not be suitable for direct-contact thermal desorption systems. For these soils, an indirect-contact thermal desorption system usually is preferred.

3.1.10 Contaminant Type, Concentration, and Distribution. This information enables material excavation planning in ex situ thermal desorption processes to allow for blending and some degree of "normalizing" of the waste to achieve a more consistent feed to the thermal desorption unit, so that it can operate more predictably. For in situ thermal desorption systems, this information can be used to configure the treatment system and its sequence (i.e., thermal well and thermal blanket treatment steps) for larger sites. Ideally, a three-dimensional representation of the contaminants of concern should be developed in either case to facilitate proper remediation planning.

3.1.11 Halogen Content. The halogen content may exceed allowable emission levels, requiring acid gas neutralization equipment, such as a scrubber. Halogenated compounds are corrosive, requiring attention to construction materials.

3.1.12 Metals Concentrations. Although it is difficult to predict the amount of metals that will be retained in the treated soil versus how much will be carried over into the gas stream, other regulatory issues may arise. For example, if the total or leachable concentrations in the treated soil exceed regulatory limits, backfilling may not be an option unless further treatment (e.g., stabilization/solidification) is performed.

Volatile metals in the waste feed will need to be managed as part of the process off-gas stream to control stack emissions. Wet scrubbers can be used to capture the volatilized metals within the circulating water stream, so they can be removed and disposed of properly in solid form.

3.1.13 Alkali Salt Content. Alkali salts can cause fusing or "slagging" of the treated residue in rotary dryer systems and in the afterburner. These conditions could present material-handling and other problems.

3.2 When to Use Thermal Desorption. Thermal desorption is potentially applicable for the treatment of a wide range of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and even higher-boiling-point, chlorinated compounds such as PCBs, dioxins, and furans. It should be considered for processing soil, sludge, sediments, and filter cakes. The technology is not effective, and is not intended for, the treatment of soils or other materials contaminated solely with inorganics such as metals. It is also not thought to be effective for the treatment of organic corrosives and reactive oxidizers and reducers. Table 3-1 summarizes the demonstrated, potential, and unexpected effectiveness of thermal desorption for a variety of contaminant groups. According to the EPA,

> *"The (thermal desorption) process is applicable for the separation of organics from refinery wastes, coal tar wastes, wood-treating wastes, creosote-contaminated soils, hydrocarbon-contaminated soils, mixed (radioactive and hazardous) wastes, synthetic rubber processing wastes and paint wastes."*

Thermal desorption has been demonstrated to be effective for remediation of pesticide-contaminated soils and sediments and wastes from manufactured gas plants.

3.2.1 Temperature Range Considerations. Figures 3-1 and 3-2 provide information from the Thermal Desorption Applications Manual for Treating Nonhazardous Petroleum-contaminated Soils (unpublished EPA report, November 1992) on soil treatment temperatures for common chemical contaminants and petroleum products, respectively. The figures indicate typical soil discharge temperature ranges achievable for the thermal desorption systems considered in this Application Guide. The bulk temperature to which the waste is heated is the first parameter to consider when choosing a treatment process. Therefore, the information contained in Figures 3-1 and 3-2 is fundamental in determining which types of thermal desorption system will likely be effective for use on a particular project. To choose the optimal technology within a temperature range, other factors should be considered, such as other chemical and physical characteristics, the quantity of waste material to be treated, the allowable timeframe, site considerations/logistics, and utility requirements.

3.2.2 Need for Treatability Studies. Bench or pilot-scale treatability studies can be performed to assess the suitability of treatment of a specific wastestream by a particular thermal desorption process. Such studies are useful in predicting the costs of full-scale operations, including the need for (and cost of) potential post-treatment fixation of the residue due to leaching. In general, for waste types remediable by thermal desorption, nearly all commercially available technologies have been shown to be successful in meeting regulatory cleanup levels. Section 4.0 details the information found in treatability studies.

Table 3-1. EFFECTIVENESS OF THERMAL DESORPTION ON GENERAL CONTAMINANT GROUPS FOR SOIL, SLUDGE, SEDIMENTS, AND FILTER CAKES

Contaminant Groups		Effectiveness			
		Soil	Sludge	Sediments	Filter Cakes
Organic	Halogenated volatiles	1	2	2	1
	Halogenated semivolatiles	1	1	2	1
	Nonhalogenated volatiles	1	2	2	1
	Nonhalogenated semivolatiles	1	2	2	1
	PCBs	1	2	1	2
	Pesticides	1	2	2	2
	Dioxins/Furans	1	2	2	2
	Organic Cyanides	2	2	2	2
	Organic Corrosives	3	3	3	3
Inorganic	Volatile metals	1	2	2	2
	Nonvolatile metals	3	3	3	3
	Asbestos	3	3	3	3
	Radioactive Materials	3	3	3	3
	Inorganic Corrosives	3	3	3	3
	Inorganic Cyanides	3	3	3	3
Reactive	Oxidizers	3	3	3	3
	Reducers	3	3	3	3

Key:
1 – Demonstrated Effectiveness: Successful treatability at some scale completed.
2 – Potential Effectiveness: Expert opinion that the technology will work.
3 – No Expected Effectiveness: Expert opinion that the technology will not work.

Source: U.S. EPA, 1991. Engineering Bulletin: Thermal Desorption Treatment. EPA/540/2-91/008.

3.2.3 Metals Contamination. Materials contaminated with organic constituents may have some metals contamination. Some thermal desorption processes are applicable for treating both organics and inorganics. Depending on the volatility and the temperature required to desorb the organic constituents, some degree of inorganic vaporization may occur. The presence of chlorine in the waste also may influence the degree of inorganic volatilization. For example, mercury contained in the waste feed vaporizes readily at the temperatures needed to desorb most organic contaminants. Other heavier metals may vaporize partially, or not very much at all, and remain contained in the treated residue at virtually the same concentration as in the waste feed.

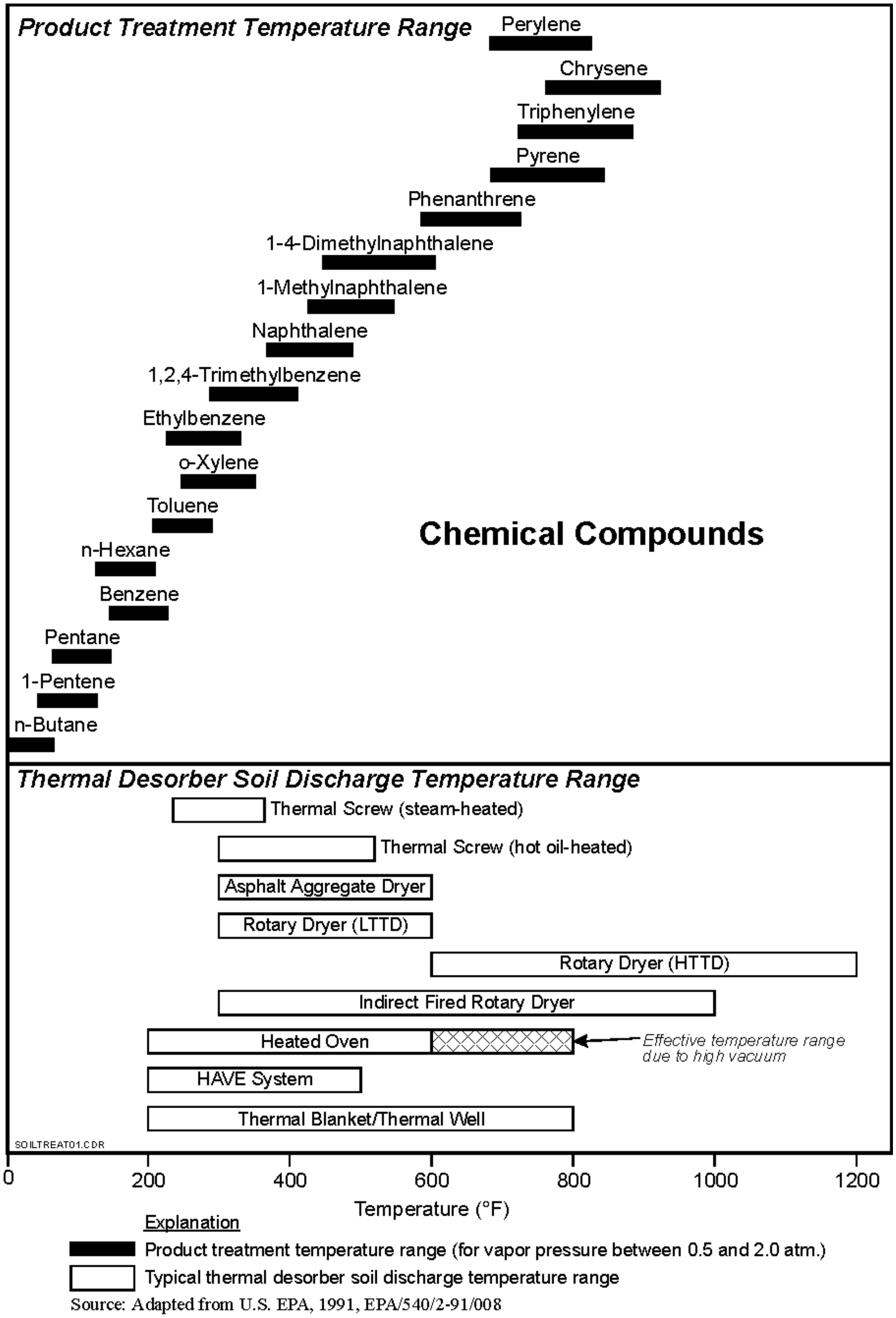


Figure 3-1. Soil Treatment Temperatures for Selected Chemical Compounds and Thermal Desorbers

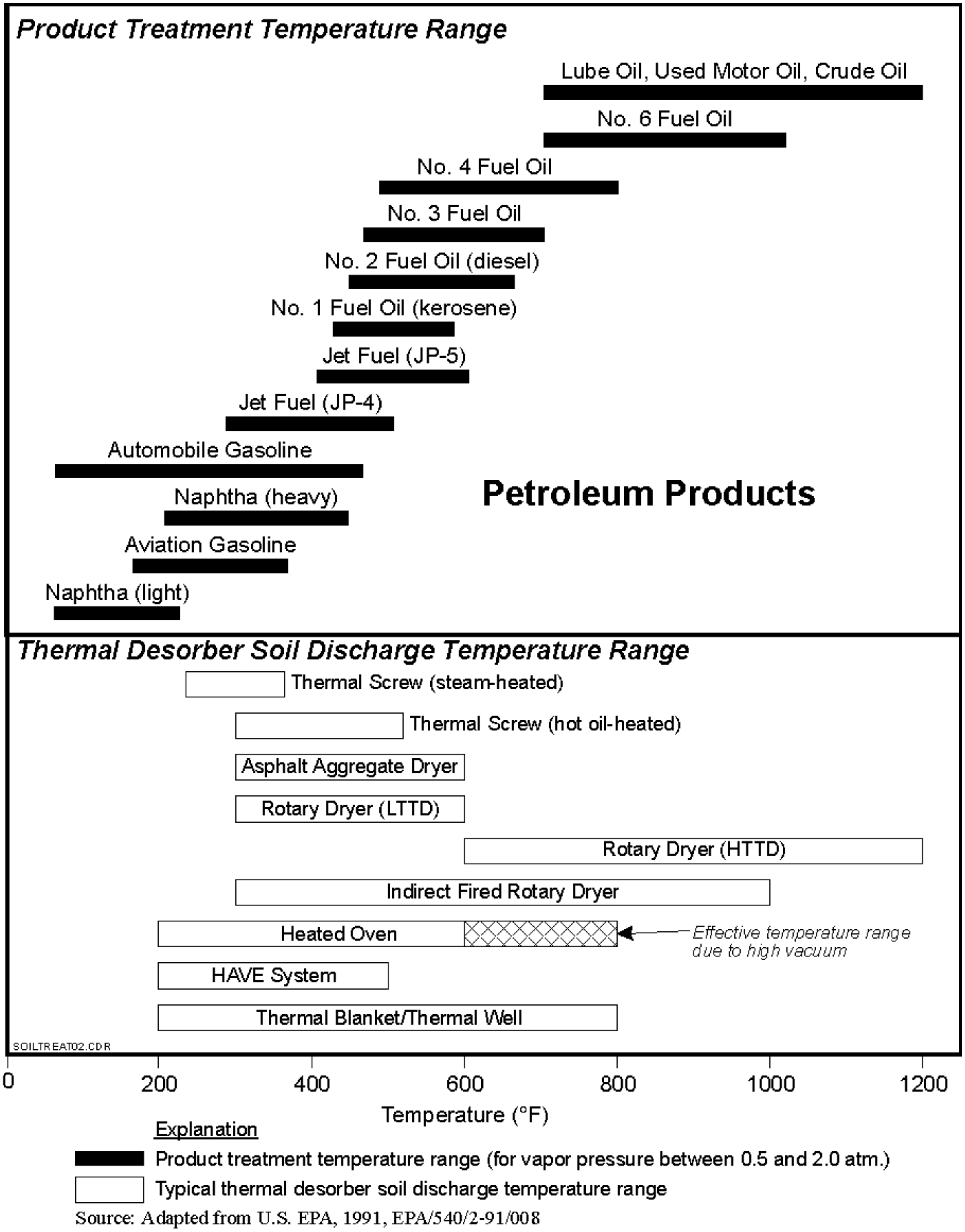


Figure 3-2. Soil Treatment Temperatures for Selected Petroleum Products and Thermal Desorber

When using a rotary dryer thermal desorption system with nonvolatile metals, it is difficult to predict how much and which of the inorganics in the waste feed will remain in the treated residue and how much will be swept out of the desorption chamber with the off-gas. The separation is referred to as *partitioning*. A material balance for metals may need to be conducted by bench- or pilot-scale testing, if the concentrations of metals are thought to be of concern compared to regulated stack emission values, or to enable successful design of the off-gas treatment and handling systems.

In addition to the concern for carryover of inorganics into the off-gas stream, even though most of the inorganics contained in the waste feed will be retained in the treated residue, the chemical and/or physical properties may be altered during the desorption process. Thus, the amount of leachable metals in the treated residue may exceed regulatory limits for redeposit of the residue on site. Because it is not possible to predict leachable amounts, TCLP testing should be done to determine if further treatment of the residue is necessary. Further treatment, when indicated, typically involves stabilization or solidification to chemically bind and immobilize the inorganics to prevent leaching. With further treatment, the total concentration remains approximately the same.

3.2.4 Decision Tree. Figure 3-3 is a decision tree to guide RPMs in determining if thermal desorption is the appropriate technology for their project. First, the RPM should establish some basic site parameters and project objectives, noted at the beginning of Figure 3-3. Next, the contaminants of concern must be known or expected to be treatable by thermal desorption. If this is the case, a series of issues, presented in question format, should be considered in arriving at the decision to use thermal desorption. Before doing so, however, Because some of the questions will not have clear “yes” or “no” answers, judgment inevitably will enter the decision process. Nevertheless, the decision tree in Figure 3-3 is a useful guide in deciding whether thermal desorption is the preferred means of remediation.

Following are some additional issues that should be considered, and some expanded versions of the questions posed in Figure 3-3.

- Are the concentrations of any inorganics or residual organics low enough that the treated materials can be disposed of readily by backfilling, or with a low-priced subsequent treatment step such as stabilization?

- Is there a time constraint? If yes, a large-scale thermal desorption unit could be used (although perhaps not cost-effectively) to quickly complete the project, because relatively high treatment rates are achievable compared to other potentially useful technologies.

- Is public acceptance of thermal treatment a concern, and is the local public likely to tolerate deployment of a thermal desorption unit to the project site?

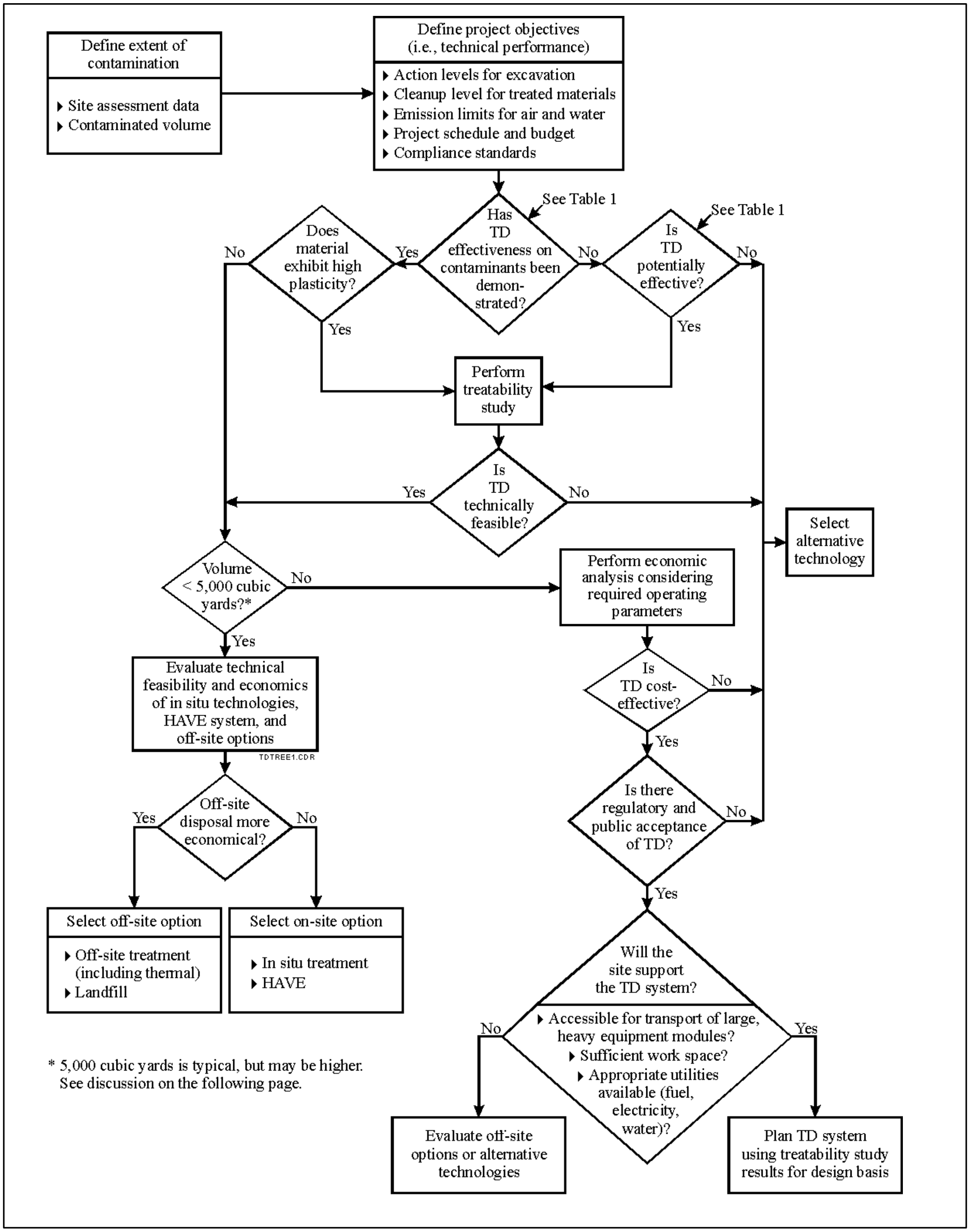


Figure 3-3. Thermal Desorption (TD) Technology Selection Decision Tree

- Are utilities (gas/liquefied petroleum gas [LPG]/fuel oil, electricity, water, etc.) available at the site in adequate supply?

- Is sufficient space available at the site for the thermal desorption system, waste feed preparation area, treated residue staging area, and water treatment system, if required?

- Will the cognizant regulatory agencies accept thermal desorption as a viable means of remediation, as differentiated from incineration?

- Is the cost of thermal desorption acceptable, based on typical rates for comparable size projects?

- The 5,000-CY volume decision point for focusing on the use of in situ thermal desorption technologies, the HAVE system, and off-site options is a typical value. The actual volume of contaminated material at which these options are more economical is site-specific and depends on many factors, such as local labor costs, proximity of the project to off-site disposal facilities, regulatory agency acceptance of thermal desorption versus incineration, and so on. At some sites, the volume decision point may be as high as 10,000 CY.

Section 4.0: DESIGN AND PERFORMANCE CHARACTERISTICS

4.1 Unit Parameters. Thermal desorption systems are grouped into two broad operational categories as continuous technologies and batch technologies. The primary design characteristics of the system designs described in this report are summarized in Tables 4-1 and 4-2 for continuous and batch systems, respectively. These design characteristic values, or ranges of values, are typical; the actual characteristic values depend on site conditions and the particular thermal desorption system design. For example, a vendor may advertise a direct-contact rotary dryer with a *nominal* soil throughput of 40 tons/hr. The actual rate is a function of soil moisture content, contaminant type and concentration, treatment standards to be achieved, and other project-specific parameters. Although 40 tons/hr throughput may be achievable when processing material with 15% moisture content, use of the same equipment at another site on otherwise identical material with 30% moisture content may result in a reduced throughput of only 25 tons/hr. The effect of site conditions on thermal desorption system performance emphasizes the importance of accurately and thoroughly characterizing a project site at the outset.

Tables 4-1 and 4-2 indicate the following general conclusions regarding the types of thermal desorption systems discussed in this document:

- Continuous thermal desorption systems have a higher throughput than batch systems and, typically, are more suited to larger projects. For very large projects, the direct-contact rotary dryer thermal desorption system is usually best suited.

- Although waste feed preparation is important for all the technologies, continuous systems have a 2-in. limit on soil feed particle size. Larger pieces must be screened, then processed through the continuous system (after size reduction) or handled separately.

- Continuous thermal desorption systems are more suited to contaminants requiring higher treatment temperatures.

- Batch thermal desorption systems require somewhat less layout area and less time for mobilization.

As noted in Section 3.2, treatability studies can be used to predict the actual unit parameters to be expected in full-scale thermal desorption operations. The U.S. EPA's (EPA/540/R-92/074 A), *Guide for Conducting Treatability Studies Under CERCLA: Thermal Desorption Remedy Selection*, *Interim Guidance*, discusses treatability testing procedures. The publication describes three tiers of treatability testing. If time is available at the outset of the project, at least some degree of treatability testing should be performed as part of developing the technical specifications. The results would be provided to bidders for the full-scale site remediation. The time and money spent on treatability testing early on may well pay for itself in terms of problems avoided or mitigated later, particularly in the case of contracted vendor thermal desorption services.

Table 4-1. DESIGN CHARACTERISTICS OF CONTINUOUS FEED THERMAL DESORPTION SYSTEMS

Item	Direct-Contact Rotary Dryer	Indirect-Contact Rotary Dryer	Indirect-Contact Thermal Screw
Soil Feed Maximum Size	< 2”	< 2”	< 2”
Maximum Contaminant Concentration in Feed	2 – 4%	50 – 60%	50 – 60%
Heat Source	Direct-Contact Combustion	Indirect-Contact Combustion	Indirect-Contact Hot Oil/Steam
Treated Soil Temperature Range	300 – 1,200°F	250 – 1,000°F	200 – 450°F
Feed Rate Achievable in tons per hour (tph)	20 – 160 tph	10 – 20 tph	5 – 10 tph
Typical Off-Gas Treatment System Used	Afterburner	Condenser	Condenser
Typical Flue Gas Cleaning System Used	Fabric Filter, Sometimes Includes Wet Scrubber	Fabric Filter, HEPA Filter, and Carbon Bed	Fabric Filter, Carbon Bed
Mobilization Time Required	1 – 4 weeks	1 – 2 weeks	1 – 2 weeks
Layout Area Required (Thermal Treatment System Only)	Small: 75 ft × 100 ft Large: 150 ft × 200 ft	70 ft × 80 ft	50 ft × 100 ft

Table 4-2. DESIGN CHARACTERISTICS OF BATCH-FEED THERMAL DESORPTION SYSTEMS

Item	Ex Situ Heated Oven	HAVE System	Thermal Blanket	Thermal Wells
Soil Feed Maximum Size	< 2”	NA	NA	NA
Heat Source	Indirect-Contact Combustion	Direct-Contact Combustion	Electric Resistance Heater	Electric Resistance Heater
Maximum Contaminant Concentration in Feed	2 – 4%	50 – 60%	50 – 60%	
Treated Soil Temperature Range	200 – 500°F (Note: Vacuum makes effective up to ~ 750°F)	150 – 400°F	200 – 500°F (estimated)	200 – 500°F (estimated)
Batch Size	One Chamber: 5 - 20 CY	300 – 1,000 CY Optimum: 750 CY	One Module: 8 ft × 20 ft	NA

Table 4-2. DESIGN CHARACTERISTICS – BATCH THERMAL DESORPTION SYSTEMS (continued)

Item	Ex Situ Heated Oven	HAVE System	Thermal Blanket	Thermal Wells
Treatment Time	1 – 4 hours	12 – 14 days	4 days	Unknown
Typical Off-gas Treatment System Used	Condensation System	Afterburner	Afterburner	Afterburner
Typical Flue Gas Cleaning System Used	Filter and Carbon Bed	Catalytic Oxidizer	Carbon Bed	Carbon Bed
Mobilization Time Required	1 – 2 weeks	1 week	NA	NA
Layout Area Required (Thermal Treatment System Only)	40 ft ×100 ft (4-unit setup)	40 ft ×100 ft for 750 cu. yds.	Variable	Variable Depending on Number of Wells

4.1.1 First-Tier Treatability Testing. The first tier of treatability testing is intended to confirm the effectiveness of thermal treatment for the specific waste matrix at the project site. Small batches of contaminated media are heated in a static tray of a muffle furnace over a range of temperatures for a variety of time periods to establish the minimum treatment temperature and residence time required by the treatment standards for the contaminants of concern. Depending on the extent of testing carried out, an understanding of the trade-off relationship of treatment temperature vs. residence time may be achieved.

The Navy could perform the first tier of treatability testing to determine whether thermal desorption would be a viable technology for a given project. The testing results would provide unit parameters so that prospective bidders could judge whether their equipment is appropriate. The cost of first-tier testing can vary from $8,000 to $30,000, according to the U.S. EPA.

4.1.2 Second-Tier Treatability Testing. The second tier of treatability testing is conducted to determine the suitability of a specific thermal desorption technology by processing a small amount of contaminated material (110 lb) in bench-scale laboratory equipment that simulates full-scale unit operations. For example, two steps of the process – thermal desorption followed by treatment and handling of the process off-gas – might be modeled separately. Appropriate thermal desorption equipment dimensions, process flowrates, and mass and energy balances for the key components would be established. Second-tier treatability testing may cost in the range of $10,000 to $100,000.

The second tier of treatability testing might be best left to prospective bidders to perform themselves. To gain access to the test results, the Navy would require that the results be included with the offerors' proposals. This course of action has the following advantages:

- The thermal desorption system vendors would design and implement the testing according to their own equipment, so the results would be more meaningful.

- The cost of testing could be reduced if vendors already have test facilities and laboratory arrangements.

- The bidders may absorb much or all of the cost of conducting the second-tier treatability testing.

- Allowing multiple vendors to run tests simultaneously would be more expedient, and different types of thermal desorption systems could be tested.

- By conducting the testing themselves, the vendors should have a higher confidence level in the results and be in a better position to interpret them based on their own thermal desorption system.

- Full-scale remediation probably would cost less, because some of the contingency that the bidders would have included for uncertain operational performance could be eliminated.

- There would be a reduced likelihood for change orders later due to claims for unexpected soil behavior during processing.

4.1.3 Third-Tier Treatability Testing. In the third tier of treatability testing, contaminated material would be processed through a pilot-scale unit that would be built in direct proportion to an existing or planned full-scale system. Because this testing involves larger equipment than used in the second tier, and the processing of up to several tons of actual material, it most likely would be carried out at the project site. The objects of this tier of testing would be, to predict to the extent possible, how an existing or planned thermal desorption system would perform on actual site material and to reveal potential problems. Alternatively, it could serve to demonstrate operational parameters and cost that were estimated from the two previous tiers of testing. In view of the time required and the cost associated with this third tier of testing (perhaps several hundred thousand dollars), it would be undertaken only for complex or unusual sites, if at all.

4.2 Utility Requirements. Fuel, water, and electricity are required to operate thermal desorption systems. These utilities are discussed in Sections 4.2.1 through 4.2.3, respectively.

4.2.1 Fuel. Thermal desorption units that are fired, either directly or indirectly, require an auxiliary fuel supply (e.g., natural gas, LPG, or fuel oil) to heat the waste to effect the separation process. The amount of fuel required depends on the following factors:

- Waste feed throughput

- Heat content of the waste feed itself

- Btu value of the auxiliary fuel

- Temperature to be attained for successful processing, which in turn depends on the properties of the contaminants to be treated

- Moisture content of the waste

- Other chemical and physical properties of the waste to be treated

- Ambient conditions

- Thermal efficiency and burner efficiency of the thermal desorption equipment.

Accordingly, it is very difficult to provide simplified guidance on the amount of fuel needed for thermal desorption operations.

4.2.2 Water. Water may be used for temperature control of the process off-gas (e.g., by direct evaporative quench); as a medium for adding chemical reagents to neutralize the off-gas; to humidify the treated residues and as make-up water for the water treatment system, if so equipped, to replace water that evaporates or is discharged to dispose of entrained substances. Most thermal desorption vendors prefer to operate in a mode in which the amount of fresh make-up water required just offsets that amount consumed by operations, if the system balance can be arranged this way, to eliminate the need to treat wastewater for discharge to allowable standards.

If the waste is excavated from below the local water table or consists of sediments that will be dewatered prior to thermal processing, the thermal desorption facility may not require a substantial amount of fresh make-up water to sustain its operation. However, during startup and shutdown, water will be required, as well as during upset conditions when perhaps a large demand may be required briefly (i.e. to prevent the overheating of FRP equipment).

Not including water obtained from the site itself that could be used by the thermal desorption system, 40 to 60 gal per ton of soil fed to the thermal desorption typically is needed to quench/humidify the treated soil to about 200^{o}F. Another 60 to 80 gal per ton of soil fed would be needed to quench/neutralize the process off-gas, if applicable.

4.2.3 Electricity. Electricity is used to operate the pump, blower, and conveyor motors; the instrumentation; and the lighting. As with the usage rate for auxiliary fuel, it is difficult to summarize electricity needs for the range of thermal desorption systems and operational factors that affect its demand. For ex situ units, a representative range might be from 0.50 to 2.0 kilowatt-hour (kWh) per ton of soil fed. For in situ thermal desorption designs, the amount of electricity consumed depends on the site conditions, ambient conditions, and depth and nature of the contamination, among other variables. The proprietary technology vendor must be consulted to provide a range of demand.

4.3 Site Considerations/Logistics. Many site considerations affect whether on-site thermal desorption is suitable for use on a particular project. The most important considerations are discussed in Sections 4.3.1 through 4.3.10.

4.3.1 Amount of Material to Be Treated. If the quantity of material to be treated is small, it may not be practical to perform on-site thermal desorption. The cost to do so, and the timeframe necessary for equipment setup, testing, awaiting test results, regulatory acceptance, production operations, etc., will point toward off-site treatment as a more viable alternative. Every situation is different, but in general the breakpoint between on-site and off-site treatment is approximately 5,000 CY of soil.

4.3.2 Proximity to Alternative Off-Site Means of Treatment or Disposal. The cost for off-site treatment or disposal involves the cost of transporting the waste material to the off-site facility, which can be significant. The risk of spreading contamination during off-site transport must be considered. Sites that are remote from off-site treatment or disposal facilities are more likely candidates for on-site thermal desorption. Generally speaking, on-site thermal desorption becomes attractive when no alternative means of off-site treatment or disposal exists within ~ 200 miles of the project.

4.3.3 Contaminants of Concern (Physical and Chemical Properties). Although thermal desorption systems are versatile in handling a wide range of contaminant types, some may not be suitable. Section 3.2 discusses the effectiveness of thermal desorption for common contaminants and the importance of relevant physical and chemical properties.

4.3.4 Local Cost/Availability of Labor and Utilities. Most thermal treatment projects are conducted 24 hr/day, 7 days/wk, resulting in a substantial amount of O&M labor. Because labor costs vary throughout the country, and the cost of operating labor can range from 10 to 50% of the unit thermal treatment cost, this factor can significantly influence the viability of on-site thermal desorption. The smaller the thermal desorption equipment to be used, the more significant the proportion of labor cost is relative to the overall unit treatment cost. For small thermal desorption systems that process only ~ 5 tons/hr, the labor cost can be 50% of the unit treatment cost. For larger thermal desorption systems used on larger projects, labor costs may be closer to only 10% of the unit treatment cost. Also, because some of the Navy’s project sites are remote, an appropriately skilled local labor force may not be available. Importing specialized craft labor to a foreign project site from the United States, if necessary, will be costly travel and living expenses.

Thermal treatment systems require utilities for operations, such as fuel, water, and electricity, as described in Section 4.2. The use of natural gas as the energy source for heating the waste typically is the most economical and reliable, but it is not always available. Overall, the percentage of the unit treatment cost represented by utility costs for thermal desorption systems ranges from approximately 4 to 30%.

4.3.5 Site Setting. Whether the site setting is industrial or residential, and whether it is urban or rural will influence the decision to treat on site. Public acceptance of the use of thermal desorption on a project often is critical to its applicability. In heavily populated areas, with many

nearby residents, the community may resist the apparent risk they perceive as being associated with the deployment of a thermal desorption system to the project site. Facilities such as schools, parks, and hospitals are considered most sensitive to thermal desorption system usage. Unplanned, emergency upset conditions, noise, and spills are often cited as reasons for concern. Appropriate community relations work and engineering controls may be required to safeguard against these perceived problems and overcome community resistance.

4.3.6 Area Available On Site. The area must be large enough to accommodate waste feed preparation, treated material staging, and possibly a water treatment system. The area required on site can be substantial, and varies among thermal desorption system types. Ex situ thermal desorption systems require 3 to 5 days of waste feed throughput available for processing to ensure that thermal treatment operations continue uninterrupted. Although thermal treatment operations usually take place around the clock, excavation to feed ex situ thermal desorption systems is performed only during daylight hours. The waste feed preparation area typically is enclosed, or at least covered, to protect it from weather and prevent rain from wetting the staged waste prior to processing.

The area where treated material is held (i.e., the staging area) depends on the thermal desorption processing rate and the time necessary to obtain laboratory results from samples taken to verify the effectiveness of the treatment process. Treated materials cannot be backfilled until confirmation is received that the treatment standards have been achieved. If an on-site lab is used, the staging area should be able to hold 2 or more days of treated materials. With an off-site lab, sample shipment time increases the amount of material that must be held.

For example, one ex situ thermal desorption system operated at a throughput of about 20 tons/hr, which is a fairly typical, mid-size system, requires approximately 50,000 ft^2.

4.3.7 Local Climate and Season of the Year. Most thermal desorption systems operate outdoors, except perhaps for the waste feed preparation area of an ex situ design. Although these systems are designed for operations in harsh climates, the excavation, material handling, and backfilling operations will be impeded by freezing weather or snow cover. Severely hot, humid weather will adversely affect the productivity of earthwork and thermal desorption system workers. The personal protective equipment (PPE) requirements mandated by the Occupational Safety and Health Act (OSHA) intensify the heat.

4.3.8 Regulatory Agency Acceptance. The RPM must gain regulatory acceptance for use of thermal desorption in lieu of actual incineration or an alternative remedial technology. The state regulatory agency typically is responsible for RCRA enforcement. Many of the Navy's hydrocarbon-contaminated sites can be treated by most types of ex situ and in situ thermal desorption. In states where contaminated media are not considered hazardous waste and the effectiveness of thermal desorption treatment has been established, acceptance by the state regulators should be obtained readily. The RPM should provide examples of sites where thermal desorption has been used successfully to treat hazardous wastes (see Section 4.4).

4.3.9 Existing Activities at the Site. A Navy base or facility with ongoing operations may not have sufficient space available for a thermal desorption system and associated activities,

especially when OSHA regulations require that much of the area used for thermal desorption and excavation be designated as restricted access. Other fire and/or safety codes may prevent locating the thermal desorption system near gas or liquid hydrocarbon storage facilities at the site.

In situ thermal desorption systems can take a long time to remediate a large area of contamination, because the heating modules treat only part of the contamination at a time and then are moved to a new area. In addition, the upper several feet and then the deeper region of a contaminated area may be treated sequentially, displacing normal activities at the site even longer.

4.3.10 Transportability of Equipment. Thermal desorption systems used for on-site remediation usually are modular, or at least transportable from site to site. Owner/operator vendors must have their modules or trailers configured to conform to road weight limits and dimensional restrictions. Limitations on interstate over-the-road freight transport are roughly as shown in Table 4-3. Exceedances are allowed in certain states based on payment of fees for special permits.

Table 4-3. U.S. OVER-THE-ROAD FREIGHT LIMITIONS

Dimension Type	Limit
Maximum width	14 ft standard, up to 17 ft with special permit
Maximum overall height of shipment, as loaded	13 ft, 6 in. standard, up to 14 ft, 6 in. with special permit
Maximum piece height (i.e., excluding truck)	8 ft, 6 in. or up to 12 ft, 6 in. with low boy trailer and special permit
Maximum gross weight	80,000 lb (includes truck weight) standard but much higher possible with special permit
Maximum length	53 ft standard limit in most states, but can range up to 70 to 80 ft with special permit
Maximum net weight	45,000 lb with standard trailer (based on an empty truck weight of 35,000 lb) or 40,000 lb when using low-boy trailer, and up to 150,000 lb possible with special permit

Several shipments up to the limits in Table 4-3 should be expected. Equipment such as the rotary dryer or a baghouse might be larger, or weigh more, than the approximate limit. The vendor would have to map a route considering bridge weight limitations, underpass openings, etc., and pay fees for a special permit from the U.S. Department of Transportation (DOT) to bring the equipment to the project site.

4.4 Previous Project Performance. Tables 4-4 through 4-10 summarize the performance of thermal desorption technologies on a variety of projects. The list of projects is not intended to be all inclusive, but is intended to show typical performance achievable. The projects are grouped according to the type of technology:

- Direct-contact rotary dryers
- Indirect-contact rotary dryers
- Indirect-contact thermal screw
- Batch feed systems – heated oven
- Batch feed systems – HAVE
- In situ – thermal blankets
- In situ – thermal wells

Table 4-4. DIRECT-CONTACT ROTARY DRYER SYSTEM

Project Name	Soil Exit Temp. (°F)	Contaminants	Soil Concentration	Treated Soil	Removal Efficiency
Old Marsh Aviation Site	730	Up to 52,000 tons of toxaphene, DDT, DDD, DDE, and other OCL pesticides	Avg.= 200-500 ppm Max = 2,500 ppm	toxaphene 1.09 ppm; DDT, DDE, DDD = 3.52 ppm	> 99%
TH Agriculture and Natrition	833-1,082	OCL pesticides	400-500 ppm	DDT < 0.13 ppm; toxaphene < 6.8 ppm	> 95%
S&S Flying/ Malone	700	5,500 tons of toxaphene-contaminated soil	634 ppm	< 1.5 ppm	> 99.76%
Port of Los Angeles Thermal Desorption	554	Petroleum Distillates	Up to 30,000 ppm	Hydrocarbons< 200 ppm; PAH < 1 ppm	> 97%
Ecotechniek	1,112-1,130	Pesticide-contaminated soil	Aldrin 44-70 ppm Dieldrin 130-200 ppm Endrin 450-2000 ppm	All 3 < 2 ppm	> 99%
NBM	1,242	Pesticide-contaminated soil	Aldrin 34 ppm Dieldrin 88 ppm Endrin 710 ppm Lindane 1.8 ppm	All 4 < 0.01 ppm	> 99%
General Motors (GM) Proving Grounds	600-900	6,727 tons contaminated with diethylbenzene	380-2,400 ppm	< 0.01 ppm	> 99%
Explorer Pipeline, Spring, TX	600-900	48,737 tons contaminated with BTEX	15,000 ppm	< 1 ppm	> 99%
Niagara Mohawk	600-1000	5,000 tons contaminated with benzo(g,h,i)-perylene	50,000 ppm	< 3 ppm	> 99%
Kelley Air Force Base, San Antonio, TX	500-1000	20,000 tons of TPH-contaminated soil	up to 5,000 ppm	< 10 ppm	> 99%
Garage in city of Brooklyn Center, MN	500-1000	Diesel Benzene Xylenes	5,600 ppm < 0.09 ppm 0.22 ppm	< 0.6 ppm < 0.03 ppm < 0.08 ppm	> 99% 66% 63%
Petroleum facility, North Adams, MA	600-1000	240,000 tons contaminated with BTEX TPH	50-1,000 ppm	< 1	90- > 99%

Table 4-5. INDIRECT-CONTACT ROTARY DRYER SYSTEM

Project Name	Soil Exit Temp. (°F)	Contaminants	Soil Concentration	Treated Soil	Removal Efficiency
Former Spencer Kellog Site	NA	6,500 tons of total VOCs	5.42 ppm	0.45 ppm	> 90%
Cannon Bridgewater	NA	11,300 tons of VOCs	5.3 ppm	< 0.025	> 99%
Ottati and Goss	NA	4,500 CY of 1,1,1-TCA TCE Tetrachloroethene Toluene Ethylbenzene Total xylenes	12-470 ppm 6.5-460 ppm 4.9-1200 ppm > 87-3,000 ppm > 50-440 ppm > 170-1100 ppm	< 0.025 ppm < 0.025 ppm < 0.025 ppm < 0.025-0.11 ppm < 0.025 ppm < 0.025-0.14 ppm	> 99% > 99% > 99% > 99% > 99% > 99%
McKin	NA	11,500 CY of VOCs and SVOCs	2.7 -3,310 ppm 0.44-1.2 ppm	< 0.05 ppm < 0.33-0.51 ppm	> 99% 75%
South Kearney	NA	16,000 tons of total VOCs and SVOCs	308.2 ppm VOCs 0.7-15 ppm SVOCs	0.51 ppm ND-1.0 ppm	> 99% > 93%
South Glens Falls Drag Site	625	PCBs	avg. = 500 ppm max. = 5,000 ppm	0.286 ppm	> 99%
South Glens Falls Drag Site	630	PCBs	avg. = 500 ppm max. = 5,000 ppm	0.181 ppm	> 99%
South Glens Falls Drag Site	646	PCBs	avg. = 500 ppm max. = 5,000 ppm	0.073 ppm	> 99%
South Glens Falls Drag Site	658	PCBs	avg. = 500 ppm max. = 5,000 ppm	0.181 ppm	> 99%
South Glens Falls Drag Site	690	PCBs	avg. = 500 ppm max. = 5,000 ppm	0.083 ppm	> 99%
South Glens Falls Drag Site	822	PCBs	avg. = 500 ppm max. = 5,000 ppm	0.040 ppm	> 99%
South Glens Falls Drag Site	842	PCBs	avg. = 500 ppm max. = 5,000 ppm	0.012 ppm	> 99%
South Glens Falls Drag Site	904	PCBs	avg. = 500 ppm max. = 5,000 ppm	0.017 ppm	> 99%
Mayport Naval Station	650	2,400 tons of petroleum-contaminated soil	TRPH from 838-13,550 mg/kg among 13 samples	TRPH of < 5 mg/kg for all samples	> 99%
Wide Beach Site	NA	42,000 tons of PCB-contaminated soil	Up to 500 ppm	avg. = 0.043 ppm	> 99%
Waukegan Harbor Cleanup	NA	13,000 tons of PCB-contaminated soil	Up to 17,000 ppm	ND	> 99%
Dustcoating, Inc.	1,100	10,000 tons of creosote-coated soil	3531 ppm	0.72 ppm	99.9%

NOTE: TCA is trichloroethane; TCE is trichloroethylene; TRPH is total recoverable petroleum hydrocarbons; ND is not detected.

Table 4-6. INDIRECT-CONTACT THERMAL SCREW SYSTEM

Project Name	Soil Exit Temp. (°F)	Contaminants	Soil Concentration	Treated Soil	Removal Efficiency
Tinker AFB, OK	NA	3,000 CY of volatiles semivolatiles	18 - 37,250 μg/kg 90 - 53,000 μg/kg	0.1 to 2.3 μg/L 6 to < 500 μg/L	> 99%
Recovery Specialists, Inc.	NA	No. 2 fuel oil	13,000 ppm	330 ppm	97.46%
Poestine, TX	500	10,000 tons diesel	20,000 ppm	80 ppm	> 99.6%
Letterkenny Army Depot	NA	7.5 tons of benzene TCE PCE Xylenes Other VOCs	590 ppm 2,680 ppm 1,420 ppm 27,200 ppm 39 ppm	0.73 ppm 1.8 ppm 1.4 ppm 0.55 ppm BDL	> 99% > 99% > 99% > 99% > 99.99%
U.S. Army-Letterkenny Army Depot	320	Benzene TCE PCE xylenes Other VOCs	586.16 ppm 2,678 ppm 1,422 ppm 27,197 ppm 39.12 ppm	0.73 ppm 1.8 ppm 1.4 ppm 0.55 ppm BDL	99.88% 99.93% 99.90% 99.99% NA
Lionville, PA Laboratory	400	Coal tar containing Benzene Toluene Xylenes Ethylbenzene Naphthalene	< 0.15 ppm < 0.15 ppm 78 ppm 14 ppm 1,200 ppm	< .005 ppm < 0.005 ppm < 0.005 ppm < 0.005 ppm 1.2 ppm	> 96.7% > 96.7% > 99.9% > 99.96% 99.9%
Petroluem Refinery #1 by Remediation Technologies	NA	Benzene Ethylbenzene Toluene Xylenes	32 ppm 44 ppm 92 ppm 154 ppm	< 1 ppm 1.2 ppm 3.9 ppm 5.9 ppm	> 96% > 97% > 96% > 90%
Petroleum Refinery #2 by Remediation Technologies	NA	Ethylbenzene Xylenes Naphthalene Phenanthrene Pyrene	24-42 ppm 57-66 ppm 96-168 ppm 127-346 ppm 11-29 ppm	< 1 ppm < 1 to 3.1 ppm < 5 ppm < 5 ppm < 5 ppm	96% +/- 90% +/- > 99% > 99% 70% +/-
Confidential – Springfield, IL	350	No.2 fuel oil and gasoline	Benzene 1 ppm Toluene 24 ppm Xylenes 110 ppm Ethylbenzene 20 ppm Naphthalene 4.9 ppm	0.0052 ppm 0.0052 ppm < 0.001 ppm 0.0048 ppm < 0.330 ppm	99.5% 99.9% > 99.9% 99.9% > 99.3%

NOTE: PCE is tetrachloroethylene; BDL is below detection limit.

Table 4-7. BATCH-FEED HEATED OVEN SYSTEM

Project Name	Soil Exit Temp. (°F)	Contaminants	Soil Concentration	Treated Soil	Removal Efficiency
Otis Air National Guard Base	NA	30,000 tons of soil contaminated with TPH and VOCs	NA	NA	Treatment in progress
FCX Superfund Site	NA	14,700 CY contaminated soil	Pesticides	1 ppm	NA

Table 4-8. BATCH-FEED — HAVE SYSTEM

Project Name	Soil Exit Temp. (°F)	Contaminants	Soil Concentration	Treated Soil	Removal Efficiency
NFESC Port Hueneme, CA	132	Soil contaminated with gasoline	Test 1: gasoline 160 ppm	ND	100%
NFESC Port Hueneme, CA	150	Diesel fuel, fuel oil, heavy oil, lubricating oil	Test 2: TPH 8,537 mg/kg	6337 ppm	26%
NFESC Port Hueneme, CA	212	Heavy oil, lubricating oil	Test 3: TPH 177 ppm	Avg. TPH 40 ppm	77%
NFESC Port Hueneme, CA	410	Same soil as test 2 after partial removal of hydrocarbons	Test 4: TPH 5,807 mg/kg	Avg. TPH 198 ppm	97%
NFESC Port Hueneme, CA	310	Mixed fuel ranging from diesel to lubricating oil	Test 5: TPH 4,700 ppm	Avg. TPH 257 ppm	95%

Table 4-9. IN SITU THERMAL BLANKET SYSTEM

Project Name	Soil Exit Temp. (°F)	Contaminants	Soil Concentration	Treated Soil	Removal Efficiency
Stegemeier/ Vinegar Test. Gasmer Road Houston, TX	Avg. 807	Hexadecane	660 - 915 ppm	0-6 in. = 0.42 ppm 6-12 in. =14.26 ppm 12-18 in. = 176.86 ppm	99.94% 98% 74.7%
South Glens Falls Dragstrip	392	PCBs	75 to 1,262 ppm Max. of 5,212 ppm	< 2 ppm	99.99999 %

Table 4-10. IN SITU THERMAL WELL SYSTEM

Project Name	Soil Exit Temp. (°F)	Contaminants	Soil Concentration	Treated Soil	Removal Efficiency
Portland, IN	NA	1,1-Dichloroethylene	0.39 - 0.65 ppm	0.001 - 0.003 ppm	> 99%
Cape Girardeau, MO	896-995	PCBs	Up to 19,900 ppm	ND to < 2 ppm	99.99999 %

Section 5.0: COST DATA

5.1 Capital Costs Factors. Capital costs for the variety of systems covered in this Application Guide vary greatly, from a few hundred thousand dollars to more than $5 million. Some of the significant factors that affect thermal desorption system cost are presented in Sections 5.1.1 through 5.1.6.

5.1.1 Treatement System Type. The type of thermal desorption technology used dramatically affects the capital cost of the system. Materials use for construction, equipment size, equipment complexity, and types of system components all affect cost. Indirect-contact systems having smaller off-gas volumes to handle and treat tend to cost less than direct-contact systems of the same size. Flue gas from indirect-contact burners does not contact the contaminated materials and, therefore, usually does not require treatment. Systems that use electricity as the heat source generally cost less for the same reason, but their operating costs may be higher if electricity is expensive at the site.

5.1.2 Treatment Temperature Capability. The higher the temperature capability of the thermal desorption system, the greater the capital cost due to more expensive construction materials, larger burners, and larger equipment to accommodate the lower-density process off-gas flow.

5.1.3 Waste Processing Throughput. Systems having larger throughput require larger and more costly equipment. Ancillaries such as conveyors also are more expensive.

5.1.4 Chlorinated Contaminant Processing Capability. Acid gas scrubbing and neutralization equipment is needed to treat chlorinated compounds. Extra equipment modules, such as acid gas scrubbers, increase the capital cost.

5.1.5 Gas Cleaning System. In addition to, or in place of, the cost of a gas scrubber, other process gas cleaning items may be necessary, such as a baghouse or a carbon adsorber.

5.1.6 Instrumentation and Control (I&C) System. The degree of sophistication of the I&C system with its alarms, interlocks, and emergency shutdown capability; the need for a continuous emissions monitoring system (CEMS); and certain specialized instruments such as opacity monitors, gas mass flowmeters, etc., can increase the capital cost of the thermal desorption system.

5.2 Capital Cost Recovery. Most remediation projects involving thermal desorption systems are carried out by contracted vendors. Thus, the client (or owner of the site) is not directly involved with the capital cost of the thermal desorption system used. The thermal desorption system's owner is responsible for ensuring that a system of appropriate type, size, and cost is proposed for the work when preparing the bid.

A financial analysis is performed to calculate the capital cost recovery for the equipment as a function of the initial investment, the prevailing interest rate, and the scheduled life of the equipment. If the vendor borrows $3 million to pay for the capital cost of a thermal

desorption system, a calculated percentage of revenue received from processing each ton (or CY) of waste material by the thermal desorption system is allocated (amortized) over the scheduled life of the equipment (e.g., 7 years) to recover the value of the initial investment and interest costs.

The scheduled life of the thermal desorption equipment for accounting purposes may not be the same as the actual, or useful, life expectancy of the thermal desorption system. The scheduled accounting life of the equipment is determined by such factors as competitive forces in the industry; the time period to obsolescence; the firm's accounting practices for other types of equipment; and the forecast for continued, expected use of the system. If a new thermal desorption system is modern and efficient enough to allow for recovery of the invested capital in, say, 4 or 5 years, while allowing the vendor to win project work competitively, its use from that point forward would, in essence, be "free" to subsequent projects, resulting in more competitive pricing and higher profit margins for the vendor.

The financial implications of capital cost recovery should help the RPM understand why thermal desorption remediation services are nearly always procured from service vendors who are continually trying to win new work. To recover the initial outlay for a thermal desorption system in a reasonable period of time, if ever, the thermal desorption system must be used frequently. There is significant capital cost outlay to purchase the equipment. If it is used sporadically, no cost recovery is realized while it is idle. If the equipment's use rate over its life is low, a loss on the initial investment may result.

Capital costs for the various types of thermal desorption equipment described in this document can range from several hundred thousand dollars for the HAVE system equipment (which alternatively can be leased, as the NFESC did during full-scale demonstration trials at Port Hueneme, California) to about $5 MM for the largest, highest-throughput, direct-contact rotary dryer systems with the capability of handling chlorinated contaminants.

5.3 Unit Rate Costs. There is a significant difference between the thermal desorption unit treatment cost and the overall unit (turnkey) cost for the entire remediation project. The unit treatment cost may be only about one-third of the overall unit cost rate, particularly if it involves deep excavation or sediment removal, which can be costly compared to simple shallow excavation. The type of thermal desorption technology employed, amount of contaminated material to be treated, contaminant concentrations and contaminated media moisture level, project location, utility availability and costs, thermal desorption unit thermal/mechanical/ operations efficiency, applicable regulatory criteria and treatment standards, and amount of sampling and analysis needed are some of the factors that affect the unit treatment cost itself and, thus, the percentage of the overall unit cost. Section 8.2 includes case study information on costs from the American Thermostat Superfund project in New York State to exemplify how these factors can affect the unit treatment cost.

Phase I of the case study involved the treatment of up to 13,000 CY of contaminated soil, and Phase II involved the treatment of up to 30,000 CY of contaminated soil. Comparing the bids for the two phases at the same site, the average bids received for the unit treatment cost dropped from $62.34/ton to $47.55/ton, even though the second phase was bid almost 3 years

later. The lower unit treatment cost reflects the economy of scale, that is, the effect of the amount of contaminated material to be treated and the use of a higher-throughput thermal desorption system. Competitive forces in existence at the two time periods, including desired profit margins, undoubtedly influenced the pricing.

Most of the vendors for both phases at American Thermostat planned to use direct-contact rotary dryer thermal desorption units. Different efficiencies among them affected the unit treatment costs. For the direct-contact rotary dryer systems bid for the Phase I case (13,000 CY of material to be treated), the unit treatment costs ranged from \$42.50/ton to \$91.56/ton, a ratio of greater than 2 to 1. The lowest unit treatment cost bid for Phase I, \$38.75/ton, was based on that vendor's intention to use an indirect-contact thermal screw unit. For the smaller project size, thermal screw technology was the most cost effective in terms of unit treatment cost alone. In terms of the overall unit cost, however, the vendor planning to use the thermal screw was not as competitive, as evidenced by his overall cost of ~ \$215/ton.

Again for Phase II most of the vendors planned to use direct-contact rotary dryer thermal desorption units. Only Bidder No. 1 planned to do otherwise, basing his price on the use of the batch-feed heated oven technology. Excluding Bidder No. 1, the unit treatment prices for Phase II ranged from \$22.81/ton to \$75.34/ton, a ratio of more than 3 to 1.

Examining the average of the bids received for Phases I and II, the unit treatment cost was only approximately 25% of the overall unit cost to perform the work. This seemingly low proportion reflects the fact that the balance of the work scope, i.e., the activities other than thermal treatment such as deep soil excavation and design/installation of a shoring and bracing system, were costly. Had the work involved only simple shallow excavation, the overall project cost would have been lower and the soil unit treatment cost would have represented a higher percentage.

In reviewing bid prices such as those from the case study, pricing strategies must be considered. The costs given in Section 8.2, taken from the actual Bid Forms submitted by the proposing vendors, may not reflect the true unit treatment costs. After developing their prices for the Bid Form activities, some of the vendors might have adjusted the distribution, to perhaps increase the unit treatment cost if they believed that the 13,000-CY quantity estimate would grow. On the other hand, if they believed that the quantity estimate was high and might not have been achieved, they might have lowered the unit treatment cost by transferring some of the treatment cost to a lump sum item such as the mobilization or demobilization bid item. Such adjustments distort the accuracy of the unit treatment cost in proportion to the overall unit cost.

Table 5-1, showing typical unit cost information for the thermal desorption technologies discussed in this Application Guide, has been assembled from various literature sources, vendor publications, and, in the case of the thermal blanket/thermal well technology which is proprietary, obtained by way of direct communication with the respective vendor. The cost information shown for the HAVE system was supplied by the NFESC and is based on actual demonstration testing conducted at Port Hueneme, California. The ranges of these unit treatment costs are quite broad, reflecting the factors discussed above. The costs should be considered representative of the relative unit treatment costs to be expected for the different technologies.

Table 5-1. TYPICAL COST INFORMATION FROM LITERATURE[(a)]

Continuous-Feed Thermal Desorption Technologies		Batch-Feed Thermal Desorption Technologies	
Small to medium, direct-contact rotary dryer	$40-$200 per ton	Heated oven	$120-$250 per ton
Large, direct-contact rotary dryer	$25-$100 per ton	**HAVE system**	$28 per ton for 11,700 tons $49 per ton for 975 tons
Indirect-contact rotary dryer	$80-$150 per ton	Thermal blanket Thermal well	roughly $100 per ton[(b)]
Indirect-contact rotary screw	$100-$150 per ton		

(a) Treatment cost only.
(b) Information obtained from personal communication with technology vendor.

5.4 Operations and Maintenance Costs. Operating costs for thermal desorption systems are a function of many parameters, as discussed in Section 5.3. Operating costs vary with the quantity of contaminated material treated. For a given thermal desorption system and the process conditions required for a particular project, utility and chemical costs are directly related to the number of tons treated. Other factors such as operating staff, maintenance provisions, and sampling and analysis costs are somewhat related to the contaminated material quantity although not necessarily directly. For example, the same thermal desorption at the same site can be operated at different throughputs with the same amount of operating staff. Likewise, maintenance costs do not necessarily double if twice as much contaminated material is processed. The savings in O&M costs when using large thermal desorption systems are responsible in part for the economy of scale shown in the typical cost information presented in Table 5-1 for a small to medium vs. a large, direct-contact rotary dryer.

On many thermal treatment projects the thermal desorption equipment may be operated around the clock, 7 days per week, depending on the surrounding community and the type of thermal desorption system. Some may produce an unacceptable level of noise in the nighttime hours. Thermal desorption contract vendors win work in large part because their operations are efficient and cost effective. Taking advantage of all available work hours makes an efficient and cost-effective vendor more competitive over the course of performing the work. Once an investment is made in a thermal desorption system, that vendor’s objective is to maintain its utilization at as high a degree as possible. If it is dedicated to one project for an extended period of time, there is a lost opportunity cost to the owner for using it on other projects. It is in the Navy’s best interest to enable round-the-clock processing operations whenever possible, to realize a lower overall cost. Typically, earthwork operations take place only during daylight hours. On projects that allow continuous thermal desorption system processing, earthwork activities must progress at more than three times the rate of treatment processing to maintain an inventory of feed material.

Operating staff requirements range from two-person crews for technologies such as the HAVE system or the in situ thermal well/thermal blanket technology to seven or more for the larger, more complex, direct-contact rotary dryer units. If the thermal desorption unit is operated 24 hr/day, 7 days/week, four crews would be needed for the 168-hr work week. In addition to direct salary costs for the operations labor, there are travel and living expense costs, so the required staffing level can have a significant impact on the overall unit treatment cost.

Maintenance costs are difficult to estimate. In addition to routine, planned shutdowns for equipment cleanouts, conveyor or baghouse inspections, refractory checkout, etc., unanticipated replacements or rebuilding requirements can occur because of the severity of service on most projects. Maintenance costs ranging from $1.00/ton of soil feed for the first 5 years of operation of a direct-contact rotary dryer system, operated 10 hr/day, 5 days/week and 36 weeks/yr, to as much as $8.00/ton of soil feed for larger, more complex, direct-contact rotary systems have been noted in the literature.

5.5 Typical Petroleum Project Cost Estimates

(Note: The information in this section is taken largely from the, "Thermal Desorption Applications Manual for Treating Nonhazardous Petroleum-Contaminated Soils" (unpublished, 1992), developed for EPA under Contract No. 68-C9-0033 by William Troxler, James Cudahy, Richard Zink (Focus Environmental), and Seymour Rosenthal (Foster Wheeler Enviresponse). Although modified somewhat for incorporation into this document, it is used with the permission of Focus Environmental and the U.S. EPA.)

This section provides a methodology for approximating typical costs for treating petroleum-contaminated soils on smaller-size projects, using the most popular thermal desorption systems. Petroleum remediation on small sites is representative of most projects undertaken by Navy RPMs.

Detailed descriptions of potential overall project tasks beyond just thermal treatment itself are provided in Appendix G. This information can be used to prepare work plans and cost estimates, or to evaluate work plans and cost estimates prepared by third parties. Sections 5.1 through 5.3 explain key factors influencing the economics of using thermal desorption technologies. Guidance is provided in this section to determine whether on-site or off-site thermal treatment is the most cost-effective option. Guidelines also are provided for determining the size of thermal desorption systems that should be considered for an onsite treatment application.

This section includes cost estimates for treating petroleum-contaminated soils with two different sizes of mobile rotary dryer systems, a mobile thermal screw system, and a stationary rotary dryer system. These are by far the most commonly used thermal desorption systems. To develop these estimates, a set of assumptions pertaining to the factors discussed in Sections 5.1 though 5.3 has been made, representing, a typical project application. Ranges of cost factors to adjust estimated treatment costs to variable site conditions are presented.

5.5.1 Small Project Tasks

5.5.1.1 Overview. A number of tasks should be considered in developing an overall project cost estimate that do not influence the evaluation or selection of alternative ex situ thermal desorption remediation technologies, or the choice of on-site versus off-site thermal treatment. These tasks are described in this report as site characterization and excavation tasks. The costs for these tasks at a specific site would be the same for the implementation of any type of on-site (ex situ) or off-site thermal desorption treatment technology. Section 5.5.1.2 identifies specific site characterization and excavation tasks and presents general cost ranges for these tasks. An underground storage tank (UST) project scenario has been selected to represent the typical small- to medium-size project for which thermal desorption might be employed.

The number and types of project tasks required to implement a thermal treatment project vary depending on whether a mobile thermal desorption system will be brought to a site or a stationary off-site thermal desorption system will be used. Section 5.5.1.3 describes tasks performed when using a mobile thermal desorption system at a site. Section 5.5.1.4 describes tasks performed when using an off-site stationary thermal desorption system.

5.5.1.2 Site Characterization and Excavation. To estimate the cost of using thermal desorption technologies, a number of site characterization and excavation cost items should be considered. A general description of tasks required to remediate leaking USTs is presented in 40 CFR Part 280, "Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks." The following tasks are included:

- Initial site characterization
- Free-product removal
- Soil and groundwater cleanup investigation
- Corrective action plan development.

One additional task, material excavation and stockpiling, must be completed before treating soils by thermal desorption. Table 5-2 presents representative cost ranges for all of these tasks.

Table 5-2. UNDERGROUND STORAGE TANK SITE CHARACTERIZATION AND EXCAVATION COST FACTORS

Remediation Task	Estimated Cost Range Low ($)	Typical ($)	High ($)	Comments
Initial site characterization	8,000	10,000	12,000	Environmental Assessment Plan to define data on the nature and quantity of the release; surrounding population; water quality, use, and locations of surrounding wells; subsurface soil conditions; locations of subsurface sewers; climatological conditions; and land use. The plan documents the results of preliminary site investigations and investigations for the presence of free product.
Free-product removal	5,000	10,000	15,000	Includes the removal of free product, disposal of recovered material, and preparing required report to implementing regulatory agency.
Investigation for soil and groundwater cleanup	5,000	20,000	50,000	Monitoring well installation, sampling and analysis to locate contaminant plume, and submission of required report to regulatory agency.
Corrective action plan development	5,000	7,500	10,000	Defines corrective action procedures to remediate soils and groundwater. Corrective action plan must be submitted to regulatory agency.
Soil excavation and stockpiling	2,500	5,000	15,000	Depends on site complexity factors, including space availability, proximity to structures, overhead clearances, location of subsurface piping, location of utilities, whether tanks are removed or left in place, and extent of hand excavation required.
Total	25,500	52,500	102,000	

Note: Estimates based on investigation and remediation of gasoline station with two 10,000-gallon tanks and 2,000 tons of contaminated soil. Costs based on January 1992 basis.
Source: Adapted from Troxler et al. (1993).

For projects not involving USTs, some of these tasks may not apply, or others may be substituted. For example, remediation of petroleum-contaminated soils from aboveground sources, such as transportation spills or spills from aboveground tanks, are not subject to the 40 CFR Part 280 requirements. Costs for remedial action tasks for contamination from these aboveground sources should be estimated on a case-by-case basis.

5.5.1.3 On-Site Thermal Desorption. The following broad categories of tasks must be completed to use an on-site thermal desorption system:

- Engineering/planning
- Procurement
- Regulatory compliance audit
- Planning/site design
- Permitting
- Site preparation
- Equipment mobilization and erection
- Performance testing
- Treatment operations
- Equipment demobilization
- Site closure.

Appendix G provides a checklist of project tasks required to use a mobile thermal treatment system. This list includes three highlighted tasks that typically would be performed by the site owner (procurement, regulatory compliance audit, and site closure). Costs for completing these tasks are defined herein as "owner costs." All of the other tasks in the list above normally would be contracted to a thermal desorption contract vendor firm. Costs for completing these tasks are referred to herein as "contractor costs." The checklist in Appendix G can be used by a site owner to verify that all required tasks have been addressed in a project cost estimate.

5.5.1.4 Off-Site Thermal Desorption. The following project tasks should be completed to treat petroleum-contaminated soils at a fixed-base, off-site facility:

- Procurement
- Regulatory compliance audit
- Soil transport
- Soil treatment operations
- Site closure.

The highlighted tasks, i.e., procurement, regulatory compliance audit, and site closure, typically would be performed by the site owner. Costs for completing these tasks are considered "owner costs." Soil transport and soil treatment operations normally would be contracted to a waste management firm, and thus are referred to in this document as "contractor costs." The checklist of project tasks in Appendix G can be used to prepare a request for quotation for procuring soil transport and thermal desorption services and to evaluate quotations for completeness.

5.5.2 Project Cost Estimates

5.5.2.1 Mobile Treatment Systems. Costs for using mobile thermal desorption systems may be categorized as either fixed costs or operating costs. Fixed costs will be incurred at each

operating site. These costs may vary from site to site but do not vary as a function of the quantity of soil to be treated. Some fixed costs increase as a function of the size of the thermal treatment system because there are more trailers to transport and more equipment to erect and disassemble. Fixed costs include procurement, regulatory compliance audit, planning/site design, permitting, site preparation, equipment mobilization and erection, performance testing, equipment demobilization, and site closure. The total fixed unit cost ($/ton) for a thermal desorption project decreases as the quantity of soil to be treated increases.

Unit treatment costs vary as a function of the characteristics of the contaminated soil; the required cleanup levels; and the type, size, and operating conditions of the thermal desorption system. Examples of unit treatment costs include capital recovery, equipment depreciation, labor, travel and expenses, health and safety, maintenance, overhead, insurance, fuel and utilities, waste treatment/disposal, and analytical costs. Unit treatment operations costs ($/ton) decrease as the waste processing rate increases, primarily because of the decrease in time required to execute the project. Key factors affecting the waste processing rate are the size of the equipment, the type and concentration of contamination, the moisture (water) content of the waste, the type of solid, and the allowable residual contamination concentration. Unit treatment costs for a given thermal desorption system and site are constant values and do not vary as a function of the quantity of material to be treated, except for very large changes in quantities.

Mobile thermal treatment alternatives can be compared by reducing all costs to an overall project cost ($/ton) that includes the sum of fixed unit costs plus unit treatment costs.

5.5.2.2 Stationary Treatment Systems. Costs for procuring and using thermal treatment services at a stationary facility include both “owner costs” and “contractor costs,” as defined in Section 5.5.1.4. Owner costs include procurement, regulatory compliance audit, and site closure. Contractor costs, including soil transportation and soil treatment operations, normally are quoted on a unit price basis ($/ton). The unit prices include capital depreciation (land, site design, site preparation, storage buildings, equipment purchase, operational plans, permitting, equipment erection, and performance testing), labor, health and safety, maintenance, overhead, insurance, fuel and utilities, waste treatment/disposal, and analytical costs.

A key variable parameter influencing the economics of using a stationary system is the cost of transporting soil from the project site to the off-site thermal treatment system. Soil transport costs must be considered in comparing the costs of using mobile versus stationary systems.

5.5.2.3 Unit Cost Factors. Table F-1 in Appendix F contains a detailed list of unit cost factors with low, typical, and high values for thermal desorption applications.

5.5.3 Project Cost Estimate Curves

5.5.3.1 Mobile Systems. A series of curves relating estimated thermal desorption treatment costs for mobile systems ($/ton) to the quantity of soil treated at a site are presented in Figures 5-1 through 5-3. Example cost curves are presented for the following types of systems:

- Large rotary dryer (7 ft diameter by 32 ft long with 40-MM-Btu/hr primary chamber burner and 40-MM-Btu/hr afterburner). System includes cyclone, baghouse, afterburner, induced-draft (ID) fan, and stack (Figure 5-1).

- Small rotary dryer (5 ft diameter by 18 ft long with 10-MM-Btu/hour primary chamber burner and 10-MM-Btu/hour afterburner). System includes cyclone, baghouse, afterburner, ID fan, and stack (Figure 5-2).

- Thermal screw (twin screws, 24 in. diameter by 24 ft long with 12-MM-Btu/hr hot oil heater). System includes condensation-type air pollution control system, condensate treatment system, ID fan, and stack (Figure 5-3).

The cost curves presented in Figures 5-1 through 5-3 include all "contractor costs" as defined in Section 5.5.1.3. The cost curves do not include any of the site characterization and excavation costs items described in Section 5.5.1.2 and do not include "owner costs" as defined in Section 5.5.1.3.

Table F-2 in Appendix F documents the assumptions used in developing Figures 5-1 through 5-3.

5.5.3.2 Stationary Systems. A set of curves relating estimated thermal desorption treatment costs for stationary systems ($/ton) to soil transport distance is presented in Figure 5-4. Example cost curves are presented for the following type of system:

- Rotary dryer (7 ft diameter by 32 ft long with 40-MM-Btu/hr primary chamber burner and 40 MM Btu/hour afterburner). System includes cyclone, baghouse, afterburner, ID fan, and stack.

Table F-2 in Appendix F documents the assumptions used in developing Figure 5-4. The cost curves presented in Figure 5-4 include all "contractor costs" and soil transport at a cost of $0.10/ton-mile. The cost curves do not include any of the site characterization and excavation cost items described in Section 5.5.1.2 and do not include "owner costs" as defined in Section 5.5.1.3.

5.5.3.3 Cost Adjustment Factor. The example cost curves presented in Figures 5-1 through 5-4 are based on the following assumptions:

- Soil moisture (water) contents of 10, 20, and 30%

- Inorganic silty soil (Unified Soil Classification System [USCS] soil classification MH; see Appendix C)

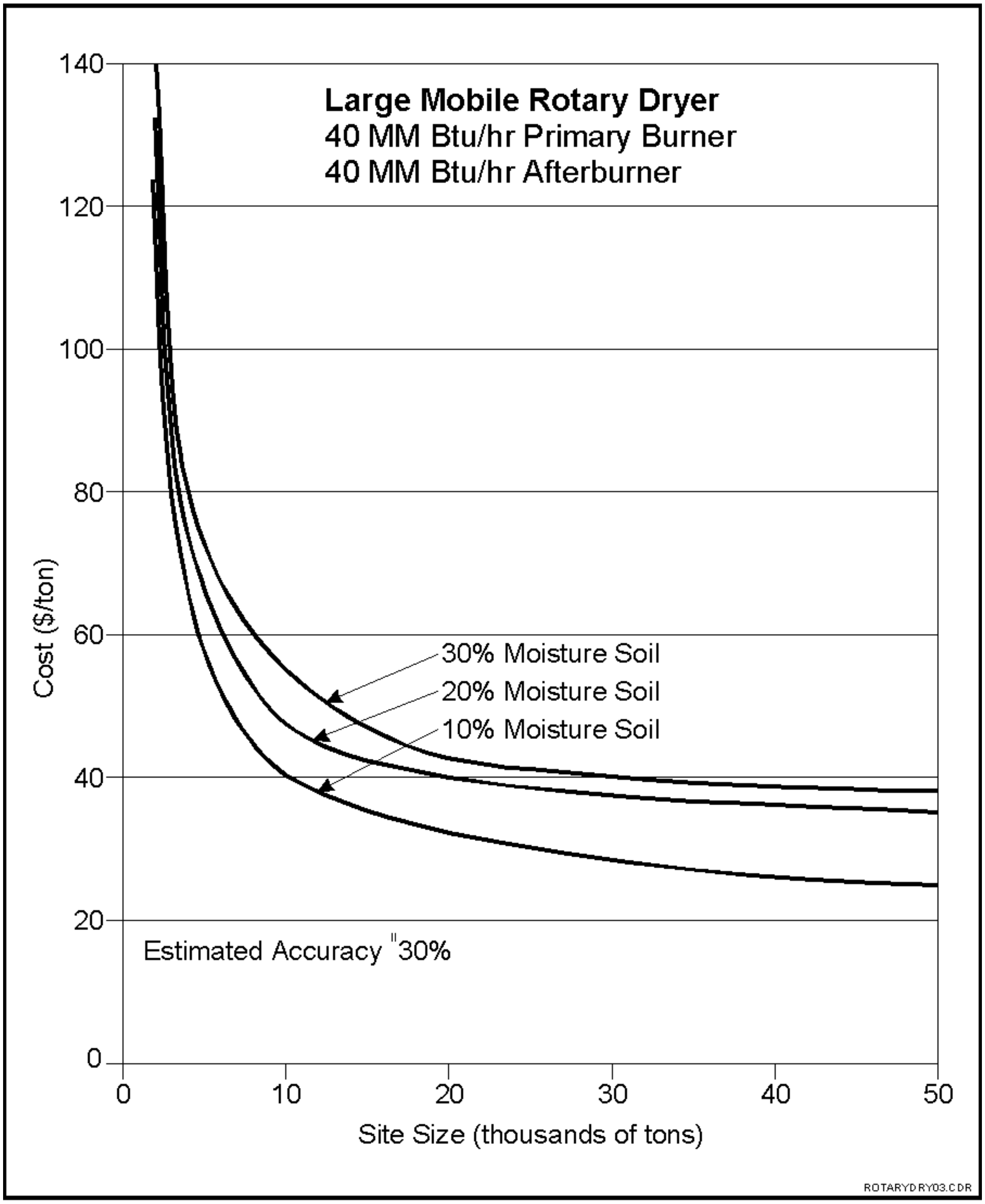
- Contaminant is No. 2 fuel oil

- Contaminant concentration is 3,000 mg/kg

- Afterburner exit gas temperature is 1,400°F for devices using an afterburner

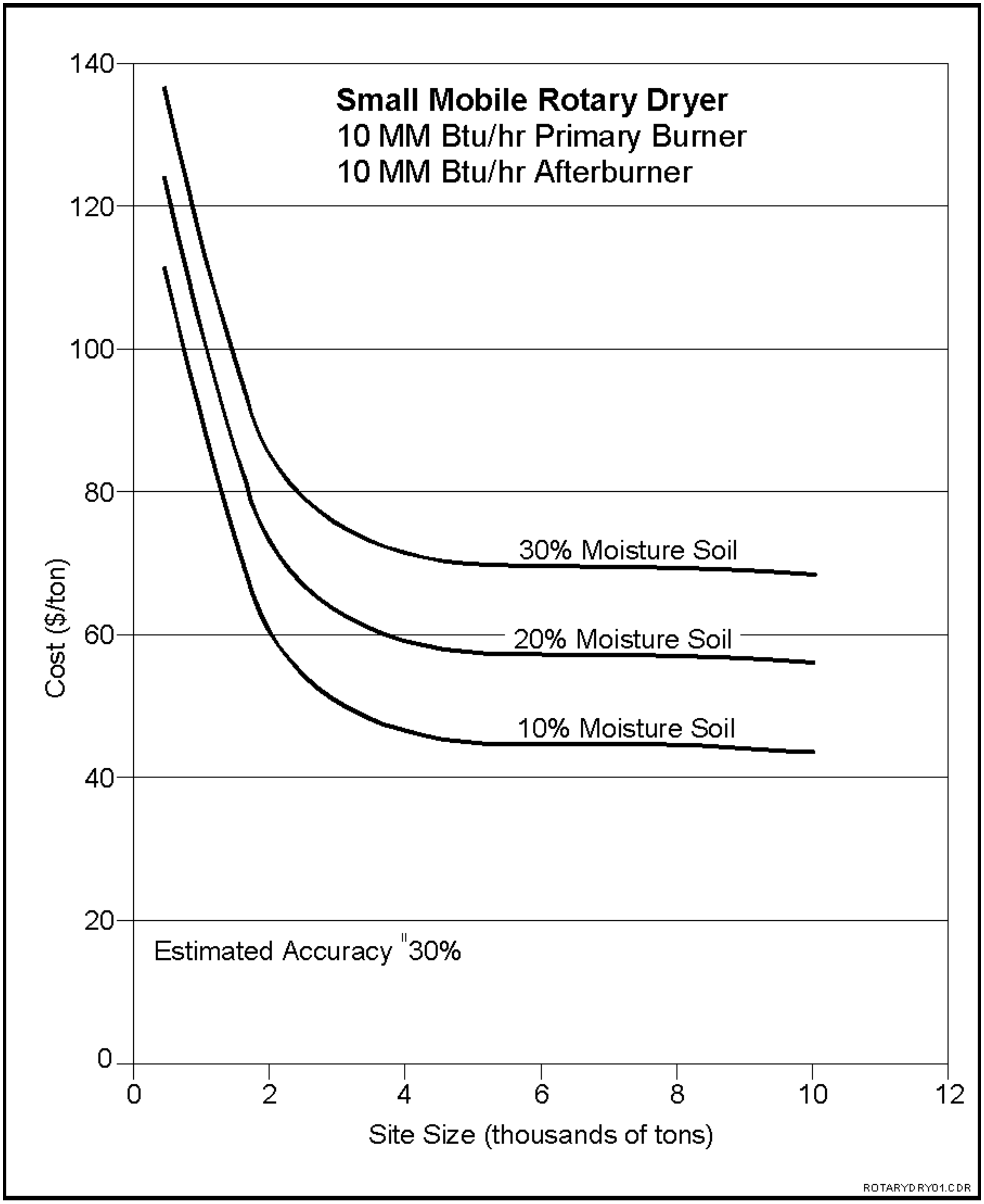
- Treated soil cleanup criterion is 100 mg/kg TPH.

Table 5-3 presents screening-level cost factors for adjusting estimated costs from Figures 5-1 through 5-4 for variations in the parameters listed above. Table 5-4 presents a blank worksheet that can be used to develop an operating cost estimate by selecting a base cost from the cost curves (Figures 5-1 through 5-4) and adjusting the base cost to account for variations in site conditions.



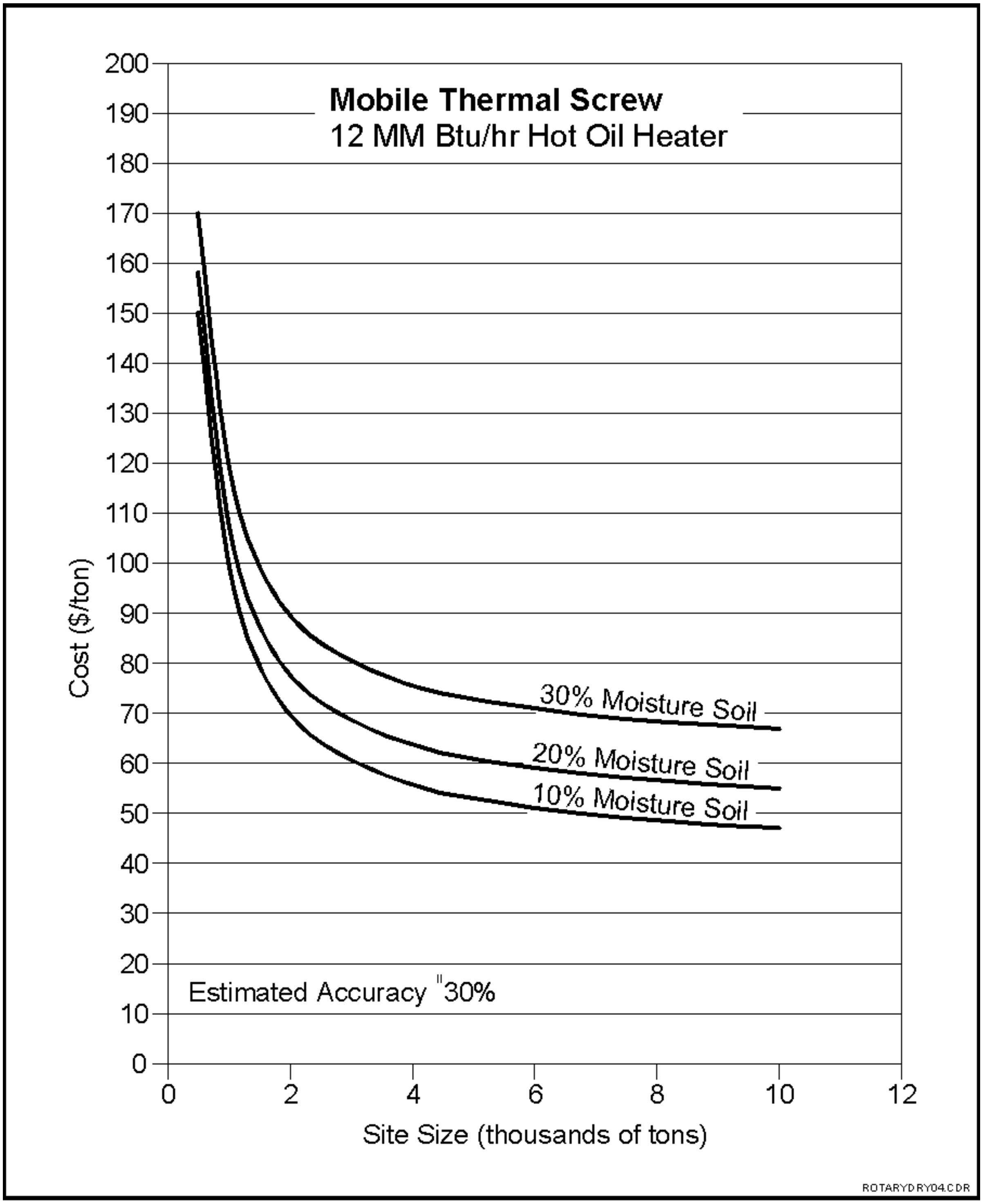
Source: Adapted from Troxler et al., (1993)

Figure 5-1. Large Mobile Rotary Dryer Treatment Costs



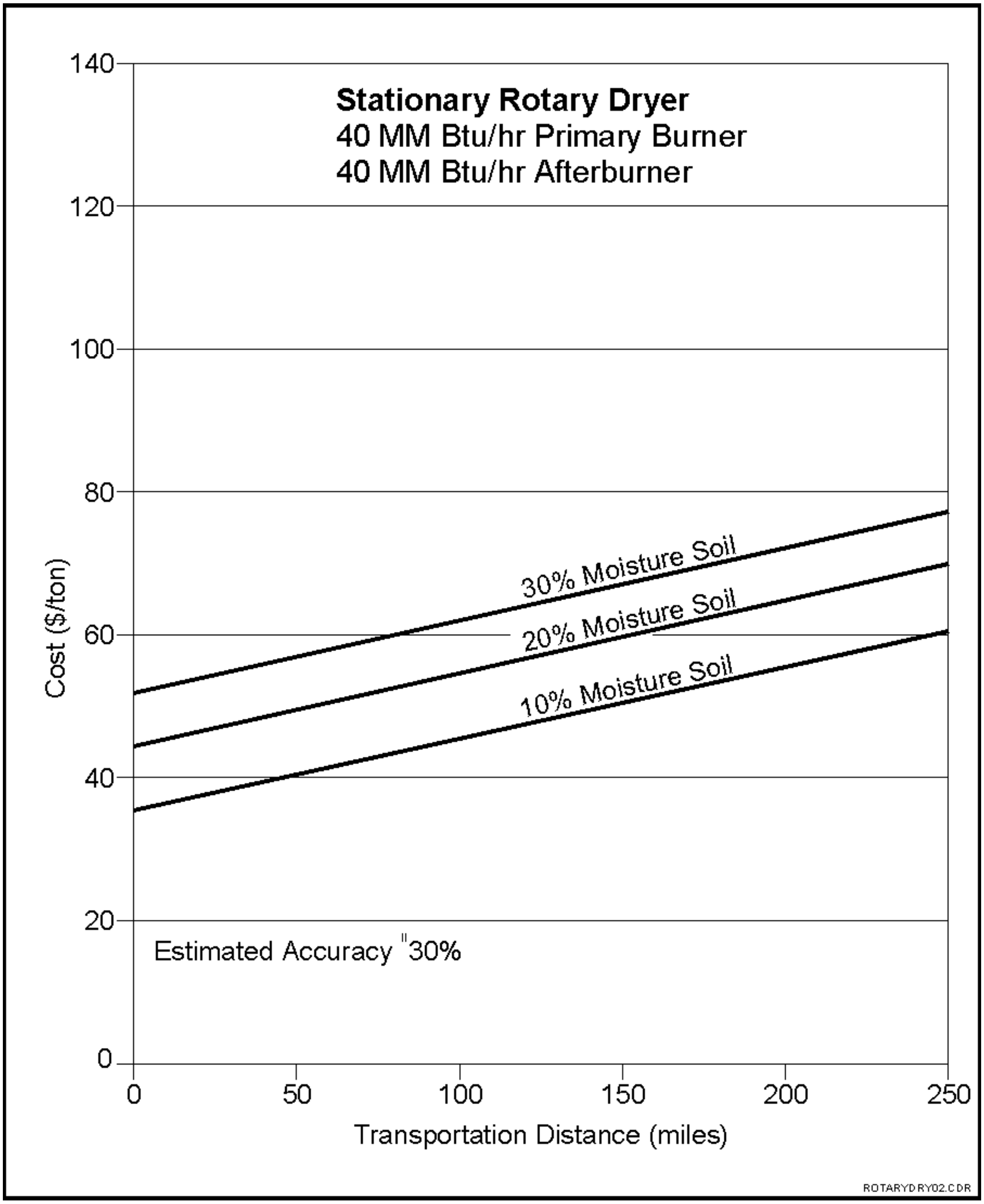
Source: Adapted from Troxler et al., (1993)

Figure 5-2. Small Mobile Rotary Dryer Treatment Costs



Source: Adapted from Troxler et al., (1993)

Figure 5-3. Mobile Thermal Screw Treatment Costs



Source: Adapted from Troxler et al., (1993)

Figure 5-4. Stationary Rotary Dryer Treatment Costs

Table 5-3. THERMAL DESORPTION TREATMENT COST ADJUSTMENT FACTORS

Cost Adjustment Parameter	Cost Curve Adjustment Factors ($/ton) [a]			
	Large Mobile Rotary Dryer	Small Mobile Rotary Dryer	Mobile Thermal Screw	Large Stationary Rotary Dryer
Contaminant Type				
Automobile gasoline, naphtha (light), naphtha (heavy), aviation gasoline, jet fuel B (soil treatment temperature 450°F)	-2.50	-4.50	-2.50	-2.50
Jet fuel A, No. 1 fuel oil, No. 2 fuel oil, No. 3 fuel oil, No. 4 fuel oil (soil treatment temperature 650°F)	0.00	0.00	0.00	0.00
No. 6 fuel oil, lube oil, used motor oil, crude oil (soil treatment temperature 950°F)	3.60	6.50	NA	3.40
Contaminant Concentration (%)				
0.30	0.00	0.00	0.00	0.00
1.00	-1.00	-1.00	14.00	-1.00
2.00	-2.00	-2.00	29.00	-2.00
Afterburner Exit Gas Temperature				
1,400°F	0.00	0.00	(b)	0.00
1,600°F	1.50	2.00	(b)	1.50
Soil Type (fine-grained) [c]				
USCS soil types ML, OL	-2.50	-6.00	-5.00	-2.00
USCS soil types MH, OH	0.00	0.00	0.00	0.00
USCS soil types CL, CH	2.50	6.00	4.50	2.00
Soil Type (coarse-grained) [c]				
USCS soil types SW, SP, SM, SC	-4.50	-10.00	-8.00	-4.00
USCS soil types GW, GP, GM, GC	-3.50	-8.00	-6.00	-3.00
USCS soil types cobbles, boulders	-2.50	-6.00	-4.00	-2.00
Soil Treatment Criteria				
TPH < 100 mg/kg	0.00	0.00	0.00	0.00
TPH < 10 mg/kg	3.50	8.50	2.50	3.00
TPH < 1 mg/kg	10.00	22.00	17.00	9.00

(a) Factors added to or subtracted from values from Figures 5-1 through 5-4. Cost factor values of 0.00 indicate that the listed cost adjustment parameter was used as the basis for developing Figures 5-1 through 5-4.
(b) Afterburner not used.
(c) USCS soil types are listed in Appendix C.
NA: Technology not applicable for this condition.
Source: Adapted from Troxler et al. (1993).

Table 5-4. THERMAL DESORPTION TREATMENT COST ADJUSTMENT WORKSHEET

Thermal Desorption Treatment Cost Adjustment Worksheet

Parameter	Value	Cost[a] Data Source	Treatment Cost ($/ton)
System Type:	______________ ______________ ______________		
Site Size (tons)	______		
Soil Moisture Content (%)	______		
Base Cost		Figures 5-1 through 5-4[b]	______
Contaminant Type	______	Table 5-3	______
Contaminant Concentration (%)	______	Table 5-3	______
Afterburner Exit Gas Temperature (°F)	______	Table 5-3	______
Soil Type (USCS Classification)	______	Table 5.4.4-1	______
Soil Treatment Criteria (mg/kg)	______	Table 5.4.4-1	______
Total Estimated Cost ($/ton)[c]			______

(a) Interpolate values from Table 5-3.
(b) Interpolate from appropriate figure to adjust base cost to measured soil moisture content.
(c) Estimate accuracy: + or – 30%.

Source : Adapted from Troxler et al. (1993).

5.6 Project Cost-Estimating Methodology. This section provides guidance on the methodology for developing cost estimates for larger and more complex projects than those considered in Section 5.5. Cost factors for large, complex projects are, by definition, difficult to generalize. A systematic approach to estimating costs is presented in the following subsections.

5.6.1 Project Work Plan. The first step in developing an accurate, comprehensive cost estimate is to develop a Project Work Plan. This Plan is a document describing the objectives of the project, the desired end results, the criteria used to define success, the constraints on the project, any assumptions that are made, and the expected schedule for all activities. The outline for the Project Work Plan would include the following topics:

- *Introduction.* This section should present an overview of the project and why it is being performed. A summary of relevant background information (e.g., brief history of the site, the cause of the problem, etc.) will be useful for those who read the document and are less familiar with the reason for the project.

- *Statement of Objectives.* This short section briefly and accurately describes the objectives to be achieved by the project.

- *Scope of Work.* This detailed section describes the scope of work required to meet the project objectives and the interface points with surrounding facilities and organizations. It should clearly differentiate activities to be performed by the Navy from those to be performed by firms that will be hired for the project. Any constraints and limitations imposed on the project should be listed and discussed.

- *Project Organization.* This section outlines the organization to be used to control and execute the project and each person’s authority and responsibility on the project.

- *Work Breakdown Structure (WBS).* The WBS divides the work to be performed into definable tasks, subtasks, and activities for which progress can be measured, down to the level at which the project will be controlled. This level should be low enough to permit adequate control of costs and schedule but not so low as to create a cumbersome and unwieldy administrative system of accounts. The WBS then becomes the basis for the project schedule, cost estimate, and financial control system.

- *Project Schedule.* Using the WBS, the project schedule should define the sequence, duration, and linkage of all activities defined in the WBS. It should highlight the critical paths of activities that directly determine the endpoint of the project. The activity numbers used in the schedule should match the WBS numbers for that activity, so that each WBS has a corresponding budget and schedule for its completion.

- *Regulatory Compliance:* This section identifies the regulatory agencies and describes the regulations that apply to the project, the cleanup criteria and emission limits the project must meet, and other applicable regulatory impacts.

Other sections may be added for site- or project-specific reasons, such as community relations or unique site requirements. For example, a section describing design criteria may be necessary if engineering design tasks are within the scope of work. Once the Project Work Plan has been approved, the project cost estimate can be completed.

5.6.2 Work Breakdown Structure (WBS). The WBS is critical to the development of a complete and accurate work scope and project cost estimate. Each major task in the project should be broken down into smaller subtasks and activities so that it can be easily estimated. However, the activities should not be so small as to involve insignificantly small costs.

The Federal Government has developed a standardized WBS for use on environmental remedial action projects called the Hazardous, Toxic and Radioactive Waste (HTRW) Remedial Action Work Breakdown Structure. This WBS lists activities that may be performed on a variety of different remedial action projects. As such, the list must be edited by the user for only those tasks that are applicable to the project under consideration. This comprehensive list of HTRW accounts was used to develop a typical WBS for a thermal desorption project, which is included in Appendix D of this Application Guide as an example.

5.6.3 Project Cost Estimate. When the WBS has been developed and the Project Work Plan has been completed, an estimate of the resources needed to complete each activity can be made. The resources are combined with the duration and timing (sequencing) for each activity in the schedule to determine the cost to complete each activity. The resources typically used to complete activities can be categorized into several standard groups, such as Professional Labor, Field Labor, Direct Materials, Construction Equipment, Permanent Equipment, Subcontractors, and Other Direct Costs (such copying, phone, expenses, etc.).

Some project costs, such as overhead costs, cannot be assigned directly to any one activity. These costs are categorized as Indirect Costs. They may be applied as a percentage of direct costs or accounted for separately. The HTRW WBS provides for a separate account for distributive costs that may then be spread to the direct costs at the end of the project.

When all activities in the WBS have been estimated, a contingency should be determined to allow for variations that may occur in actual costs during project execution. The contingency may be estimated on a percentage of costs basis or by estimating the potential variances in projected costs and assigning a dollar value. The contingency is to cover costs associated with errors that may have occurred in the design or estimate, or due to incomplete scope definition of all the activities for the project, inadequacy of information available at the time the estimate is done, compensation for incorrect assumptions made, and the variability of site conditions. If these areas of the project are very well defined, the contingency may be very low. However, as uncertainty increases, so should the contingency.

This cost estimate will be used as the government estimate used to evaluate bids during the procurement process, the baseline budget against which actual project costs will be measured, and the baseline scope of work for assistance in determining when changes occur in the project.

Section 6.0: CONTRACTING STRATEGIES

6.1 Government Ownership. The overwhelming majority of environmental remediation projects involving thermal desorption are carried out via turnkey, contracted service. For example, in 1996 the Navy successfully completed a project of this type at Naval Station Mayport in Jacksonville, Florida.

There are many reasons for contracting services rather than purchasing equipment, some of which are noted as follows:

- *The state of the technology is always changing.* Because of rapid changes, some designs become obsolete in just a few years. For example, the heated oven form of thermal desorption has evolved into three designs over the last several years to correct operational problems, make it more versatile and competitive, and make it suitable for PCB remediation.

- *There are significant financial cost implications associated with owning most types of thermal desorption equipment.* When the equipment is idle, depreciation and capital recovery costs continue. If the equipment is not utilized to a high degree over its useful life, the overall cost of purchase increases significantly.

- *No single thermal desorption design is optimal, or even applicable, to all projects.* Because of the specificity of each project, technical specifications developed for the contracting approach usually are performance oriented, without actually stipulating details of the thermal desorption system design.

- *In some applications, the optimal thermal desorption technology may be proprietary.* The technology may not be available for purchase by the Navy. For example, the innovative, patented, thermal well/thermal blanket means of in situ thermal treatment was developed as a result of years of experience in the oil exploration and production industry. Its efficient use requires hands-on experience in geologic/hydrogeologic effects, subsurface thermal gradient modeling, and geotechnical problem solving. The vendor owning the technology completed a contract with the Navy to conduct a demonstration project at Mare Island, California as part of the BADCAT program.

- *Not all thermal desorption designs are considered to be "nonincinerators" by regulators.* Thermal desorption designs that involve treatment of the process off-gas by combustion are viewed as incinerators by some regulatory agencies. Given the value of not having to comply with incineration regulations when they are not necessary for a particular application, ownership of a specific thermal desorption design may result in added cost and schedule delays associated with the perceived use of incineration.
- *For organizations such as the Navy, which is involved in a large variety of small projects separated by great distances, the cost to repeatedly disassemble/*

transport/ reassemble a thermal desorption system will outweigh any benefit of owning the equipment. It is more cost-effective to contract with a local firm for the service, as done for the Naval Station Mayport project. Moreover, for small projects involving less than ~ 5,000 CY of material to be treated, it may be more economical to send the contaminated media off site for treatment and/or disposal (if allowable). Organizations choosing to purchase their own thermal desorption unit would tend to operate it as a fixed-base facility used to process a steady, consistent wastestream from the plant where it resides, or from several nearby locations.

Some commercial treatment firms use a transportable-type thermal desorption unit that is normally fixed at a particular location. Usually the waste is brought to the thermal desorber, but when there is a shortage of waste from various clients or an opportunity to conduct treatment at the project site, the firm might temporarily dispatch the thermal desorption unit to the project location. This attempt to maintain a high utilization rate for the thermal treatment equipment underscores the importance of addressing the significant financial implications associated with ownership of the equipment.

- *The more successful vendors offering contracted thermal desorption services have developed an invaluable knowledge base of how to perform the work from executing prior projects.* These vendors maintain experienced staff to retain the efficiency and resourcefulness that helped them prosper, and to allow them to continue to be competitive.

- *Leasing thermal desorption equipment presents several potential problems.* Trained and experienced O&M staff, who are familiar with the equipment, must be obtained for a successful project. Most successful remediation firms that own transportable systems retain their key staff and move them from project to project. For example, even labor unions, which are eager to supply competent workers for projects, have recognized that certain O&M positions are specialized and equipment-specific, and have deferred to the owner company's highly skilled employees. In addition, contract thermal desorption remediation firms typically maintain an extensive spare parts inventory at the project site to minimize downtime when a part needs to be replaced. For a leased thermal desorption system, the spare parts supply probably would be maintained at the location of the equipment owner so that the Navy, as the leasor, might lose time in waiting for spare parts.

- *Equipment modifications in the field are delayed when using leased equipment.* Virtually every thermal treatment project ever carried out has required equipment modifications in the field to rectify operational problems. These modifications sometimes must be made immediately to correct a situation that is hindering or preventing processing. When leasing equipment, the Navy could encounter logistical problems, or at least delays, in implementing the need for equipment modifications that arise suddenly.

In conclusion, it is not advisable for the Navy to own or lease thermal treatment equipment that requires a significant capital outlay, specialized staffing, and maintenance; may be limited in its range of applicability; is large and difficult or costly to transport; and is unproven in terms of reliability. These criteria cover most thermal desorption designs, including the direct-contact and indirect-contact rotary dryer types and the thermal screw conveyor discussed in this document. The heated oven technology and the thermal well/thermal blanket are proprietary designs that cannot be purchased by the Navy. Among the thermal desorption systems most commonly used in the United States and described in this Application Guide, only the HAVE system seems appropriate for ownership by the Navy. Continued usage of the HAVE system technology should lead to further refinement and increased operational efficiency for smaller projects, making it a valuable tool for consideration at Navy facilities worldwide requiring remediation.

6.2 Subcontracting Considerations. There are many vendors, i.e., owner/operators, active in the field of thermal desorption, some having multiple types or sizes of equipment that allow them to pursue a variety of projects from a competitive standpoint. Because the field is evolving, and new companies are entering the market while others may not have survived, it is good practice to scrutinize the track record of vendors under consideration for an upcoming project. The Navy should be skeptical of those companies that have not been in the thermal treatment business very long, because less capable firms leave the industry regularly as a result of inexperience in bidding and executing projects.

A review of successful projects has shown that the preferred vendor to select is, most often, the one that appears to present the “best value” for the upcoming project. Best value can be arrived at by assessing the categories shown in Table 6-1 when reviewing proposals:

Because evaluation of these many issues in Table 6.1 is subjective, several individuals should review the proposals independently. Proposals should be requested from offerers in three distinct volumes or sections :

- I – Technical Approach
- II – Qualifications of Key personnel/Past Experience of the Firm
- III – Price

Table 6-1. Categories to be Assessed in Selecting Best Value

Technical Approach	Qualifications of Key Personnel	Past Experience of the Firm
• Understanding of the project/overall technical approach • Thermal treatment system design • Earthwork activities and general construction methodology • Site layout for project activities • Considerations for severe weather effects • Ancillary systems' design (e.g. wastewater treatment system) • Health and safety • Quality control • Regulatory compliance • Off-site transport and disposal plans • Overall schedule with key milestones	• Project management organization • Key personnel resumes • Qualifications of key subcontractors • Small business/small disadvantaged business (SB/SDB) team subcontractor participation (for government projects)	• General/hazardous waste construction experience • Project-related experience • Past client references

The topics are split to allow for unbiased consideration of the evaluation criteria. For example, a reviewer who knows that a particular offeror has a relatively high total price may be inclined to superficially review the Technical Approach segment of the proposal. This is counter to the objective of arriving at the offeror who presents the best value overall. A recommended proportioning of the evaluation criteria categories is shown is Table 6-2.

Table 6-2. Evaluation Criteria Weightings

Criterion	Weight
Price	30%
Technical Approach	25%
Past Experience of the Firm	20%
Qualifications of Key Personnel	25%
TOTAL	100%

The weighting of the price component of the overall evaluation is greater, but not necessarily dominant, in arriving at a final score. If a bidding firm offers a reasonable price, but

not the lowest price, yet has a superior technical approach and better past experience and qualifications of key personnel than a lower bidding competitor, it could be judged to offer a "better value" overall than simply selecting the lowest bidder.

Some important questions to consider in evaluating prospective firms, in addition to pricing, are as follows:

- Has the vendor worked on a similar project (size, contaminants, site constraints, etc.) before?

- Does the vendor's technical approach to the new project appear sound? Is the proposed schedule to accomplish the work reasonable?

- Will the vendor be self-performing a significant degree of the overall project with his/her own resources?

- Can the vendor obtain performance and payment bonds from a credible surety?

- Are the vendor's references satisfactory?

- With the vendor' organization, are the lines of communication and administration conducive to successful project execution? Are the vendor's personnel well qualified, and is it known specifically who will work on the upcoming project?

- What are the vendor's technical resources?

- Does the vendor appear to be adept at the regulatory/permitting types of requirements?

- On past projects, has the vendor shown a propensity to file claims?

6.3 Thermal Treatment Bid Form. A representative Bid Form for a thermal desorption project is shown in Table 6-3. Some elements are stipulated as "Lump Sum," and others are designated as Unit Cost (i.e., "Each" or with the standard of measurement indicated). In general, aspects of the project that can be defined completely enough so that a bidder can price them confidently are solicited as lump sum. Often lump sum pricing is required for activities that cannot be fully defined, or whose magnitude is not predictable with certainty, such that the bidder must incorporate excess contingency in the bid. This not only builds in extra cost for the solicitor, but causes difficulty in assessing whether a bidder understands the scope of work and whether the level of understanding among various bidders is satisfactory. The situation could result in hiring a firm that misunderstood the project until after award, at which time the relationship with the owner or construction manager, or the NFESC, would become adversarial.

For bid items that legitimately cannot be defined well enough to convey adequate scope definition for lump sum pricing, or if the quantities are indeterminate or expected to grow during the course of the work, it is appropriate to request unit prices based on an estimated total

quantity. Treatment quantities nearly always are unit-priced due to the uncertainty in knowing the final amount, because the end point for earthwork typically depends on post-excavation sampling results.

Table 6-3 shows a graduated scale for excavation/treatment/backfill quantities for both item 9 (i.e., 9a, 9b, 9c) and item 10 (i.e., 10a, 10b, 10c) to allow the bidder to show different unit prices for the quantity breaks. For example, the minimum amount of Shallow Excavation, Treatment, and Backfill is 4,000 CY. If the quantity grows to between 4,000 and 6,000 CY, the bidder may use the strategy of quoting a lower unit price for that portion, because certain fixed costs related to the treatment quantity may decline due to the greater total amount treated. For the next increment, from 6,000 to 7,000 CY, the bidder again may elect to offer a lower unit price for the same reason.

The 4,000 CY of shallow material and the 14,000 CY of deep material (per Bid Form items 10a, 10b, and 10c) represent the minimum quantities of shallow and deep material that the successful vendor can be assured of treating. A potential vendor must know the minimum treatment amount to decide if his/her equipment can be competitive on the project.

For bidding purposes, a distinction is made between shallow and deep material because the treatment and earthwork costs should be greater for deep material than for shallow material. For example, it costs more to excavate and backfill soil at 30 ft below grade than near the surface. Also, because moisture content is higher and the degree of large rock to be encountered at lower depths is greater, material-handling and processing costs should be more for deep material. A logical breakpoint between shallow and deep material might be the water table elevation (if this is within ~ 10 ft of ground surface), because soil taken from the unsaturated zone will be drier than that taken from the saturated strata. In general, moisture content exceeding 20% for waste soil fed to a rotary dryer thermal desorption will have an impact the unit treatment cost. Below 20% moisture content, the actual amount of water in the soil is inconsequential, with the unit treatment cost being controlled by other parameters.

The final *expected* maximum total quantities are 7,000 CY (i.e., 4,000 + 2,000 + 1,000) for the shallow and 23,000 CY (i.e., 14,000 + 5,500 + 3,500) for the deep, for an overall total of up to 30,000 CY of soil to be treated. However, an overrun quantity category is requested for bidding purposes because, depending on post-excavation soil sampling results, either of these could be exceeded more than anyone expected when developing the bid specifications. For the shallow material 1,800 CY and for the deep material 5,800 CY represent up to an approximately 25% exceedance on the expected combined maximum of 30,000 CY. The 25% value is arbitrary, but is meant to go beyond the ±15% stipulated in the Federal Acquisition Regulations (FAR). Pricing is requested from bidders at the time of bid so that prices for this unexpected, but potential, situation are obtained under competitive conditions. Alternatively, if an overrun occurs near the end of the project, with a vendor already under contract having completed much of the work, the leverage would be on the side of the thermal desorption contractor because, for a relatively small extension of work, the owner or construction manager could not solicit new competitive bids for the overrun quantity as a new project.

Table 6-3. TYPICAL THERMAL TREATMENT BID FORM

Item Number	Description	Estimated Quantity	Unit	Unit Price	Amount
1	Mobilization, Demobilization, and Site Services	X	Lump Sum	X	
2	Health and Safety Requirements	X	Lump Sum	X	
3	Chemical Sampling and Analysis	X	Lump Sum	X	
4	Air Modeling and Monitoring	X	Lump Sum	X	
5	Mobilize, Test, and Demobilize the Low-Temperature, Enhanced Volatilization Facility (LTEVF)	X	Lump Sum	X	
6	Mobilize, Operate, and Demobilize the Water Treatment System (WTS)	X	Lump Sum	X	
7	General Site Preparation	X	Lump Sum	X	
8	Control of Water	X	Lump Sum	X	
9	**Shallow Excavation, Treatment, and Backfill:**	X	X	X	X
9a	Shallow Excavation	first 4,000 next 2,000 next 1,000 next 1,800*	CY CY CY CY		0
9b	Treatment of Shallow Excavation	first 4,000 next 2,000 next 1,000 next 1,800*	CY CY CY CY		0
9c	Shallow Backfill	first 4,000 next 2,000 next 1,000 next 1,800*	CY CY CY CY		0
10	**Deep Excavation Treatment and Backfill:**	X	X	X	X
10a	Deep Excavation	first 14,000 next 5,500 next 3,500 next 5,800*	CY CY CY CY		0
10b	Treatment of Deep Excavation	first 14,000 next 5,500 next 3,500 next 5,800*	CY CY CY CY		0
10c	Deep Backfill	first 14,000 next 5,500 next 3,500 next 5,800*	CY CY CY CY		0
11	Residue Fixation	2,000	Ton		
12	Drum and Debris Handling	48	Each		
13	**Shoring and Bracing:**	X	X	X	X
13a	Design of Shoring and Bracing System	X	Lump Sum	X	
13b	Installation of Shoring and Bracing	X	Lump Sum	X	
13c	Removal and Decontamination of Shoring and Bracing	X	Lump Sum	X	
14	Confirmatory Soil Sampling	250	Each		
15	Site Restoration	X	Lump Sum	X	
16	Additional Off-Site Air Monitoring	3	Each		
17	Mob/Demob of Plant for Fixing Residue	X	Lump Sum	X	
18	TCLP Testing for Pb and Cd	300	Each		
---	**TOTAL**	---	---	---	

* These items are potential overrun quantities for which a unit price should be provided but <u>are not</u> to be included in the TOTAL.

Separate pricing is requested for excavation, treatment, and backfill activities for the shallow and deep material cases because these activities are performed at different times. For payment purposes it is desirable to know, at a given point in time, how much soil has been excavated, separate from how much has been treated, separate from how much has been backfilled. Because it is never advisable to pay a contractor for more than the value of work actually performed, or costs actually incurred (in the case of purchased items), these unit price activities should be tracked individually. In this way the contractor might be paid for excavating, say, 10,000 CY at the end of a month when he might only have thermally treated 6,000 CY of the material and backfilled just 2,000 CY. Furthermore, because there are lags between material being treated, receipt of preliminary analytical results demonstrating that the treatment was successful (i.e., that the treatment standards were achieved), and the receipt of validated analytical results confirming successful treatment, one may want to further break down the treatment payment basis according to these measurable milestones.

Some activities on the Bid Form may be eliminated in their entirety, if information is not available when the technical specifications are prepared. A good example of this is Bid Form item 11 in Table 6-3, Residue Fixation. It is usually unknown, or highly uncertain, how much, if any, of the treated residue eventually will require treatment beyond thermal processing. Individual pricing for this item can be requested. If it is deleted altogether, the exact amount of reduction in the contract price is known already. If the potential cost for residue fixation is included as part of the treatment cost, disagreements could transpire during execution of the project over the value of the fixation cost component because the contractor would be inclined to give up very little of the unit price for treatment due to the elimination of fixation.

In addition to structuring the Bid Form for ease in payment administration during execution of the work, a Measurement and Payment section normally is included as part of the technical specifications part of the contract. The Measurement and Payment section is used to describe the timing and percentage of progress payments to be made for each lump sum activity and any conditions stipulated for payment of unit quantity items. For example, for item 1 of the example Bid Form, the Measurement and Payment may designate that 25% of the value of the item is payable after the successful completion of mobilization activities, 25% after the successful completion of demobilization, and the remaining 50% in equal monthly allotments following mobilization.

Section 7.0: REGULATORY COMPLIANCE ISSUES

7.1 General Regulatory Issues. Two categories of regulatory issues must be considered prior to implementing the thermal desorption technology:

- *Siting regulations.* These regulations impact the construction or placement of the technology in a particular place (Section 7.1.1).

- *Operational regulations.* These regulations impact how the technology is operated and the various inputs and outputs of the unit (Section 7.1.2).

Naval facilities usually present an entire array of regulatory issues that fall under both categories.

7.1.1 Siting Regulations. The siting regulations associated with the thermal desorption technology are not unlike the regulatory issues faced by engineers who are planning to construct a large facility. The siting issues at Naval facilities usually revolve around the fact that most facilities are located near water bodies. In addition, Naval facilities are federal facilities, which complicates the issue of state law compliance.

Siting laws typically prohibit the placement of a thermal desorption unit in a regulated area such as a wetland or coastal zone. In most cases, placement or construction will be regulated through a permitting process. For example, thermal desorption units cannot be placed in wetland areas or wetland buffer or transition zones without first obtaining a permit. Permits involve an administrative process that may include filing an application, paying fees, appearing before special boards of inquiry and public meetings, and providing technical data and supporting material. Permits may also contain special conditions that may be quite onerous and which may involve mitigation work such as the restoration or creation of wetlands following site closure.

7.1.2 Operational Regulations. Operational regulations usually involve more difficult regulatory requirements for the thermal desorption technology. These regulations typically regulate the input and output of the unit through rigorous permitting processes and/or technology evaluation processes to determine whether the technology is correct for the job. Clean Water Act and Clean Air Act permitting may be required to set acceptable pollutant emission levels and to create a monitoring scheme to ensure that the regulatory limits are continuously met. RCRA regulations also require permitting as well as meeting design, operational, and monitoring requirements.

7.2 Specific Regulatory Issues

7.2.1 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Regulations. CERCLA regulatory issues for the thermal desorption technology tend to be complex, as they are part of a highly publicized national program requiring projects to meet stringent programmatic and cleanup requirements. CERCLA does not apply to petroleum products but may apply to sites contaminated with petroleum constituents (BTEX, etc.). The

major CERCLA issues associated with implementation of the thermal desorption technology are discussed in Sections 7.2.1.1 through 7.2.1.4.

7.2.1.1 Remedy Selection Criteria (CERCLA 121(b)). 40 CFR 300.430 outlines nine selection criteria for choosing a remedial technology:

- Overall protectiveness
- ARAR compliance
- Long-term effectiveness
- Reduction of toxicity
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance.

Each criterion must be satisfied before a technology can be accepted in the U.S. EPA's Record of Decision (ROD). The ROD authorizes the application of the technology at a particular site and provides a public record of the decision-making process. The ROD also sets the regulatory parameters and cleanup levels that will be applied to the thermal desorption unit.

7.2.1.2 Compliance with ARARs (CERCLA 121(d)). CERCLA remedial technologies must comply with all Applicable or Relevant and Appropriate Requirements (ARARs). ARARs include promulgated regulatory requirements as well as technical guidance materials that are "to be considered" when implementing the cleanup. However, compliance with ARARs is limited to "substantive" not "administrative" requirements. Substantive requirements are usually numeric criteria such as cleanup standards or effluent limitations or may include design criteria such as secondary containment requirements. Administrative requirements usually include applications, fees, reports, appearances before review boards, or any other procedural requirement that may delay the cleanup.

7.2.1.3 CERCLA Permitting Requirements (CERCLA 121(e)). Permits are not required for CERCLA activities that are conducted entirely on site. Usually, *on site* will be defined in the ROD or in another administrative document. In most cases, EPA will define the *site* as the extent of contamination above and below the ground surface. Some states take exception to this broad definition of *site* and have successfully challenged the permit exception in court. Even though permits are not required, cleanup contractors who implement the thermal desorption technology still need to meet the substantive requirements of the permit regulations. For example, a National Pollutant Discharge Elimination System (NPDES) permit may not be required for on-site discharge of wastewater at a CERCLA site, but compliance with numeric or narrative discharge limits will be required.

7.2.1.4 Federal Facilities (CERCLA 120). Naval facilities are "federal facilities" under CERCLA, and thus are subject to and must comply with CERCLA to the same extent as any nongovernmental entity. Accordingly, Naval facilities can be investigated by the U.S. EPA and placed on the National Priorities List (NPL). As NPL sites, Naval facilities are subject to the

National Contingency Plan (NCP), which requires compliance with the Remedial Investigation/Feasibility Study (RI/FS) and the ROD processes for remedy selection. In addition, in some cases, DoD uses the NCP as a "guidance" for non-NPL facilities that require cleanup under DoD's voluntary cleanup programs. Although this policy provides a "blueprint" for the cleanup, such voluntary action does not necessarily avail the site of the permit and administrative requirement exemptions.

7.2.2 Resource Conservation and Recovery Act (RCRA) Regulations. RCRA regulates the generation, treatment, storage, and disposal of hazardous wastes. Generator requirements involve the proper handling of wastes and documentation requirements such as the use of a hazardous waste manifest to track wastes from cradle to grave. Generator requirements may apply to facilities using the thermal desorption technology if wastes remain hazardous following treatment. In most of these cases, residues will be disposed of off site at a permitted treatment, storage, or disposal facility (TSDF).

A Part B permit must be obtained for a TSDF prior to operation or interim status. Part B permitting subjects thermal desorption treatment to the TSDF requirements, which include numerous procedural and design requirements for treating and storing wastes as well as strict closure and post closure requirements. In addition to the permitting requirements, RCRA has a corrective action program that mandates remediation at RCRA TSDFs. All of these elements may impact the design and implementation of the thermal desorption technology.

7.2.2.1 RCRA-Regulated Wastes. RCRA applies to "hazardous wastes." Solid wastes can be classified as hazardous wastes in two ways: First, the RCRA regulations contain a number of "listed" hazardous wastes that have been determined to be hazardous by rule (40 CFR 261.31 through 261.33). Under the regulations, listed wastes maintain their hazardous nature regardless of concentration. Listed wastes may be "de-listed" through a lengthy administrative process. The second way in which wastes can be classified as hazardous waste is through characterization testing. These types of hazardous wastes are called "characteristic " wastes which are defined as solid wastes that exhibit one or more hazardous characteristic (toxicity, reactivity, ignitability, or corrosiveness as defined in 40 CFR 261.21 through 261.24).

7.2.2.2 Contaminated Environmental Media. Environmental media must be managed as a hazardous waste if the media (1) exhibit a hazardous characteristic above regulatory limits; or (2) "contain" a listed hazardous waste according to the U.S. EPA's "contained-in" policy. Thermal desorption systems can treat soils until they no longer exhibit the hazardous characteristic or until they "no longer contain" the listed waste. The proposed Hazardous Waste Identification Rule (HWIR) for contaminated media is designed to uniformly quantify when media "no longer contain" a listed waste. This rule is expected to be promulgated in 1998. Until then, each state has a means by which they determine when environmental media "no longer contain" hazardous wastes. States use a variety of "contained-out" levels including state cleanup criteria, risk-based levels, or TCLP levels.

7.2.2.3 RCRA Permitting. Part B permitting for thermal desorption systems may be required under RCRA if the unit is treating hazardous waste. Because there is no specific thermal desorption category under RCRA regulations, the thermal desorption technology may be

characterized as an incinerator, an industrial furnace, or a miscellaneous unit. A key element of these permitting regulations is the Destruction and Removal Efficiency (DRE) criteria. If permitting under RCRA is required, the thermal desorption technology must attain a 99.99% destruction efficiency, unless the unit is handling PCBs or dioxin-contaminated wastes where the DRE required is 99.9999%.

7.2.3 RCRA Exclusions for Petroleum-Contaminated Soils. Two exclusions for treating petroleum-contaminated soils may apply to thermal desorption technologies as described in Sections 7.2.3.1 and 7.2.3.2.

7.2.3.1 Petroleum Contaminated Soils Subject to Underground Storage Tank Regulations. 40 CFR 261.4(b)(10) defines certain wastes that are excluded from being classified as hazardous wastes. Petroleum-contaminated soils that would fail the TCLP defined in 40 CFR 261.24 for waste codes D018 through D043 are exempt from RCRA regulations if they are subject to regulation under the UST regulations listed in 40 CFR Part 280. These regulations govern the design, construction, installation, operation, spill and release detection, reporting and investigation requirements, and corrective action and closure requirements for USTs. Soils that fail the TCLP criteria for waste codes D001 through D017 are not exempt under this provision.

7.2.3.2 RCRA Recycling Exemption. RCRA regulations provide an exemption for hydrocarbons that are recycled in accordance with 40 CFR 261.6(3)(v through vii). If the concentration of petroleum compounds is high enough to make recycling worthwhile, the contaminated soils may be eligible for this exemption. However, most contaminated media concentrations are not high enough to make recycling economical, so this exemption would not apply.

7.2.4 Toxic Substances Control Act (TSCA). TSCA regulations are described in 40 CFR Part 761 and cover the standards for the treatment, storage, and disposal of soils and other materials contaminated with PCBs in concentrations of 50 mg/kg or higher. If the site in question is being remediated under CERCLA regulations, the selected technology must meet the substantive requirements of TSCA regulations, as described above. Soils contaminated with PCBs over 50 mg/kg may be treated by thermal desorption systems, if the technology is approved by the U.S. EPA, and generally must be able to achieve a treated soil concentration of 2 mg/kg or less.

7.3 Soil Cleanup Levels. Table 7-1 provides the numeric cleanup levels for soils derived from federal regulatory programs. Table 7-2 provides the numeric cleanup levels for soils derived from state regulatory programs for coastal states where most Naval facilities are located. These cleanup levels are applied to soil/solid treatment technologies, such as thermal desorption, for petroleum-based constituents. Most states have industrial levels that supplement the residential cleanup levels provided below. The levels in the tables present the lowest cleanup levels available for the purposes of evaluating the appropriateness of the thermal desorption technology and reasonable operating parameters. Accordingly, these tables do not provide all of the cleanup levels for any particular regulatory program or state regulation.

Appendix E summarizes the soil cleanup criteria for all states. This summary was reprinted with the permission of the publisher from the November 1997 issue of *Soil and Groundwater Cleanup*.

As evident from the tables in Appendix E, soil cleanup criteria vary widely from state to state and even within a given state. In addition, regulations are constantly changing and evolving for the states. Before implementing thermal desorption or any other technology, the appropriate state and local agencies should be contacted to determine the current regulatory criteria.

Table 7-1. FEDERAL REGULATORY PROGRAMS SOIL CLEANUP LEVELS (ppmw)

Program	Benzene	Toluene	Ethylbenzene	Xylenes[1]	Petroleum Hydrocarbons
RCRA[2]	None	20,000	8,000	200,000	None
BIF[3]	0.005	10	None	None	None
TCLP[4]	0.05	None	None	None	None
UTS[5]	10	10	10	30	None
SSLs[6]	22	16,000	7,800	160,000	None
EPA IX[7]	1.4	1,900	690	990	None
RBSLs[8]	5.82	13,300	7,830	1,450,000	None

Notes: [1] Mixed isomers unless otherwise noted.
[2] Proposed corrective action levels (July 1990).
[3] Residue concentration limits pursuant to the RCRA BIF Rule.
[4] Toxicity Characteristic Leaching Procedure hazardous waste levels (mg/L).
[5] Universal Treatment Standards for non-wastewaters.
[6] Superfund Soil Screening Levels; ingestion pathway – surface soils
[7] EPA Region IX Preliminary Remediation Goals.
[8] ASTM risk-based screening levels for petroleum release sites; ingestion pathway – surface soils.

Table 7-2. COASTAL STATES SOIL CLEANUP LEVELS (ppmw)

State	Benzene	Toluene	Ethylbenzene	Xylenes[1]	Petroleum Hydrocarbons
Northeastern					
Connecticut[2]	21	500	500	500	500
Delaware	10[3]	NA	NA	NA	100-1,000[4]
Massachusetts[5]	10	90	80	500	500
New Hampshire[6]	0.2	75	75	750	10,000
New Jersey	3	1,000	1,000	410	10,000
New York	0.06	1.5	5.5	1.2	None
Pennsylvania[7]	0.8	100	70	1.0	500
Rhode Island	None	None	None	None	None
Southeastern					
Alabama	None	None	None	None	None
Florida	None	None	None	None	10
Georgia[8]	0.02	14.4	20	1,000	None
Lousiana	100[3]	None	None	None	300
Maryland[9]	None	None	None	None	None
North Carolina	None	None	None	None	10-300[10]
South Carolina	None	None	None	None	10-100[11]
Texas	0.5	100	70	1,000	None
Virginia	None	None	None	None	None
Washington, DC	1.0	10	10	10	100
Western					
Arkansas	10-100[3]	None	None	None	50-2,000[12]
California[13]	0.1	10	68	175	10,000
Hawaii[14]	0.05	10	1.4	None	None
Oregon[15]	0.1	80	100	800	40-1,000[16]
Washington	0.5	40	20	20	100-200[16]

Notes:
[1]Mixed isomers unless otherwise noted.
[2]Direct exposure levels.
[3]Total BTEX cleanup levels.
[4]100 ppmw corresponds to gasoline; 1,000 ppmw corresponds to diesel and waste oils.
[5]Corresponds to S-1 & GW-1 cleanup levels for soil and groundwater.
[6]Represents "generic" cleanup levels.
[7]Soil to groundwater pathway.
[8]Notification requirement triggers; not cleanup values.
[9]Cleanup levels developed on case-by-case basis.
[10]Range based on test method employed.
[11]Range based on proximity to aquifer.
[12]Range based on source of contamination.
[13]Values are for contamination located >150 feet above the groundwater table.
[14]Values are based on proximity to drinking water sources for leaking underground storage tank (LUST) sites only.
[15]Residential with pathway to groundwater.
[16]Range based on gasoline or other petroleum contamination.

Section 8.0: CASE STUDIES

This section summarizes two soil remediation by thermal desorption projects that are typical of the types of projects the Navy may encounter at various sites. The first is a small petroleum-contaminated soil project that was performed at the Mayport Naval Station in Mayport, Florida in 1996. The second involves a larger project that was performed by the U.S. EPA at a site contaminated with chlorinated organics near Albany, New York. These two projects were selected because it was felt that they represent the two extremes that the Navy might encounter, i.e., a small nonhazardous petroleum-contaminated soil project and a large, hazardous waste project that was required to meet RCRA regulatory performance standards.

8.1 Example Case Study: Mayport Naval Station, Mayport, Florida

8.1.1 Project Background. This section was adapted from a report provided by the NFESC titled, "Overview of Thermal Desorption Technology," (CR-98.008). The purpose of this project was to excavate, remediate via low-temperature thermal desorption, backfill, and compact approximately 2,400 tons of petroleum-contaminated soil (as defined in the Florida Administrative Code [FAC] 62-775.200) located in Solid Waste Management Units (SWMUs) 6 and 7 at the Oily Waste Treatment Plant (OWTP), Mayport Naval Station (NS Mayport), Mayport, Florida.

NS Mayport entered into an agreement with Southwest Soil Remediation, Inc. (SSR) in accordance with the Work Order under Contract 95-D-0978. Remediation activities began April 15, 1996 and were completed May 9, 1996.

On-site work included the following:

- Soil excavation
- Mobilization
- Equipment decontamination
- Treatability test and full-scale technology demonstration
- Soil remediation process
- Decontamination
- Demobilization.

On December 19, 1995, SSR obtained an air emissions permit from the Florida Department of Environmental Protection (FDEP) for the on-site treatment of nonhazardous petroleum-contaminated soil (PCS).

Emissions stack testing of the thermal desorption system was conducted on April 15, 1996 for the following parameters with the thermal desorber operating at a maximum feed rate of 7 to 10 tons per hour (tph):

- Particulate matter (PM) emissions by EPA Methods 1, 2, 3, 4, and 5

- Carbon monoxide (CO) emissions by the continuous CO monitor during the PM test

- Afterburner temperature by the continuous temperature monitor during the PM test

- Afterburner residence time using the test data collected by EPA Methods 1 and 2 during the PM test.

SSR initially excavated approximately 960 tons of PCS located in SWMUs 6 and 7 at the OWTP. Due to the depth of groundwater in the work area, SSR excavated to a maximum depth of 5 ft below ground surface (bgs). Excavated PCS was separated into five 20-ton stockpiles and one 860-ton stockpile. The five 20-ton stockpiles were utilized for the initial treatability test, and the 860-ton stockpile was utilized for the full-scale technology demonstration.

SSR screened out oversized material greater than 2-in. in diameter. Oversized material and debris from the excavation was stored on site to be disposed of by NS Mayport.

The excavated PCS was stockpiled in a bermed storage area lined with 10-mil plastic. The storage area was located on the asphalt parking/storage lot, approximately 50 yd from the thermal desorber. Noncontaminated excavated soil was stockpiled in a 23,400-ft^2 area that had been designated by NS Mayport.

SSR thermally treated the PCS, which was representative of all of the soil to be treated during the treatability test. The treatability test operated approximately 12 hr/day during operation on April 15, 1996 and April 16, 1996. Once the treatability test had been completed on April 16, 1996, full-scale treatment (24 hr/day operation) commenced and was completed on May 4, 1996. Upon initiation of the full-scale operation, approximately 1,440 tons of additional PCS was excavated from SWMUs 6 and 7. Approximately 1,920 tons of soil were excavated from the sludge pond area and approximately 480 tons of soil were excavated from another area, for a total of approximately 2,400 tons.

Pretreatment and remediated soils were sampled according to the proposed soil sampling protocol outlined in the FDEP regulation document titled *Quality Assurance Standard Operating Procedures Manual for Soil Thermal Treatment Facilities* (STTF SOP), dated November 1991, and detailed in the Scope of Work.

Remediated soil was stockpiled in the soil storage area prior to backfilling. Treated soil was placed in the lined and bermed storage area, pending analytical results. After analytical results indicated the soil had been treated to meet regulatory thresholds, the treated soil was stockpiled outside of the bermed soil storage areas near the excavation in a grassy, nonimpacted area previously designated by NS Mayport.

Following treatment and confirmation that residual contamination levels were below regulatory thresholds, SSR backfilled and compacted the treated soil on May 7, 1996 through May 9, 1996. Backfill and compaction activities consisted of placing treated soil in the excavation and compacting the soil with a wheeled loader.

Once backfilling and compacting activities had been completed, SSR decontaminated the thermal desorber. Dust accumulated from the decontaminating procedures was deposited in a lagoon area, north of the work site. Approximately 1/3 ton of oversized material and debris was generated from the remediation activities and disposed of by NS Mayport.

8.1.2 Soil Remediation Process. The excavated PCS was fed into the 3-CY cold feed bin with a front-end loader. The soil was transported by conveyor into the rotary dryer, where the temperature of the soil was elevated to between 650 and 700°F within ~ 6 to 10 min. Flue gas exited the dryer and passed through a baghouse for particulate removal.

The dust collected from the baghouse was mixed with the rotary drum soil discharge via a screw auger and rehydrated to minimize dust and prepare the soil for use as backfill. The particle-free exhaust gases were forced through the thermal oxidizer. The thermal oxidizer exhaust gases were combusted and the VOCs in the exhaust gases were destroyed at a minimum of 99% efficiency at the maximum hydrocarbon loading anticipated for the project. The treated air was emitted to the atmosphere. Table 8-1 shows the system information.

Table 8-1. THERMAL DESORPTION SYSTEM INFORMATION

Item	Description
Desorber type	Direct-contact rotary dryer
Soil exit temperature	650 to 700°F
Soil feed rate	7 to 12 tph (Average = 8 tph)
Off-gas treatment	Afterburner
Afterburner operating temperature	Over 1,500°F
Flue gas cleaning system	Fabric filter

8.1.3 Treatability Testing and Sampling. On April 15, 1996 and April 16, 1996, approximately 100 tons of excavated PCS was thermally remediated during the treatability test. The thermal desorption rotary dryer processed an average of 8 to 10 tph for the treatability test. Based on the efficiency of the thermal treatment process in removing contaminants from the soils, the processing rate was adjusted up to 12 tph to maximize the efficiency of the thermal treatment system.

Each 20-ton batch of PCS was treated separately. One sample was collected and analyzed for each 20-ton batch, for a total of five samples. Samples were collected on April 15, 1996 and April 16, 1996 by performing hourly subsampling on each 20-ton batch, composited from two separate grabs of soil from the discharge conveyor.

Treatability testing results were received by SSR on April 17, 1996. Analytical results were compared with regulatory thresholds established in the QCP. According to the analytical data, the treated soils did not exceed these regulatory thresholds and were classified as “clean soil” in accordance with FAC 62-775.400.

8.1.4 Full-Scale Technology Demonstration and Post-Treatment Sampling. Based on the treatability test results, the thermal desorption was capable of treating the PCS to below the regulatory thresholds stated earlier. Therefore, the full-scale technology demonstration of thermally treating the soil commenced on April 17, 1996. SSR began treating the remaining 860 tons of PCS. An additional 1,440 tons of PCS, for a total of 2,400 tons, were excavated and stockpiled in the work area. The thermal desorber averaged 8 tph.

From April 17, 1996 through May 4, 1996, a total of 49 post-treatment samples were collected from the thermal unit during the full-scale technology demonstration. Post-treatment soil samples were collected from the discharge conveyor and analyzed using the methods shown in Table 8-2.

Table 8-2. ANALYTICAL METHODS AND REGULATORY THRESHOLDS USED IN POST-TREATMENT SAMPING

Parameter	EPA Method	Regulatory Standard
Volatile Organic Analysis (VOA)	8020	100 μg/kg
Total Recoverable Petroleum Hydrocarbons (TRPH)	3540/9073	10 mg/kg
Metals		
Arsenic (As)	3050/6010 and 7471	10 mg/kg
Barium (Ba)	3050/6010 and 7471	490 mg/kg
Cadmium (Cd)	3050/6010 and 7471	37 mg/kg
Chromium (Cr)	3050/6010 and 7471	50 mg/kg
Lead (Pb)	3050/6010 and 7471	108 mg/kg
Mercury (Hg)	3050/6010 and 7471	23 mg/kg
Selenium (Se)	3050/6010 and 7471	389 mg/kg
Silver (Ag)	3050/6010 and 7471	352 mg/kg

Based on the soil processing rate of 8 tph, treated soil was stockpiled in 64-ton batches in the treated soil storage area. Water spray was used to control fugitive dust. The treated soil remained in this area until the post-treatment analytical data results confirmed that the soil had been treated to below the regulatory thresholds shown in Table 8-2.

After treatment, composite soil samples were collected in accordance with FAC 62-775.410(5). Subsamples were collected from the discharge conveyor hourly over each 8-hr operational period and composited, in accordance with the protocol specified in the QCP. The thermally treated soil samples were analyzed for VOA, TRPH, and total metals. Analytical results were compared with the established regulatory thresholds. The treated soils did not exceed these regulatory thresholds, and the soil was classified as “clean soil” in accordance with

FAC 62-775.400, as shown in Table 8-3. Treated soil that complied with the regulatory thresholds was returned to the excavation or temporarily stored in one large stockpile in the treated soil area.

Table 8-3. THERMAL DESORPTION TEST RESULTS

Parameter	Pretreatment Concentration (mg/kg)	Post-Treatment Concentration (mg/kg)
TRPH	2,463 to 13,550	< 5
As	< 2	< 2
Ba	< 20 to 57.3	< 20
Cd	< 1 to 3.1	< 1
Cr	< 1 to 38.3	1.2 to 4.8
Pb	< 1 to 55.8	< 1 to 13.8
Hg	< 0.01 to 5.6	< 0.01 to 0.04
Se	< 2	< 2 to 3.8
Ag	< 2	< 2

8.1.5 Decontamination and Demobilization. SSR completed processing the PCS on May 4, 1996. The thermal desorption system was decontaminated using the procedures in the STTF SOP. The dust accumulated from the decontamination activities was deposited in the existing lagoon area, north of the work site. The thermal desorption system was transported from the NS Mayport site on May 9, 1996.

8.1.6 Cost. The total cost for the project was approximately $200,000 including planning, excavation, treating contaminated soils, and backfilling treated soils in the original excavation areas.

8.2 Example Case Study: American Thermostat Superfund Project, South Cairo, New York

8.2.1 Project Backgound. The American Thermostat Superfund Site in South Cairo, New York is located about 30 miles southwest of Albany. It is the location of the former American Thermostat Plant where thermostats for small appliances were assembled from 1954 to May 1985.

The site is approximately 8 acres in size and is located in a predominantly rural, residential area of New York State, more than 100 miles from New York City. During the former plant’s activities, tetrachloroethene (PCE) and trichloroethene (TCE) were used in the manufacturing process. Improper disposal practices by the plant’s employees, involving the dumping of spent PCE and TCE solvents on the grounds, resulted in contamination of the site soil (i.e., subsequently the “source” during remediation activities) and, shortly thereafter, the groundwater. Over the ensuing years, as contamination leached from the source, a sizable contaminated groundwater plume emanated from beneath the site property. PCE and TCE were designated as listed hazardous wastes, bearing RCRA waste codes F001 and F002.

At some point during the early site investigation phase, the American Thermostat Company went out of business. The U.S. EPA inherited the responsibility to remediate the site and designated it as a Superfund site. Immediately thereafter, the U.S. EPA commissioned the performance of an RI/FS to fully characterize the site and determine the most favorable means of remediation. As part of the ROD process, it was decided that several Operable Units, or stages of the remedial process, would be implemented. One of the Operable Units concerned remediation of the source area. A low-temperature enhanced volatilization facility (LTEVF), in essence low-temperature thermal desorption, was to be utilized for remediating the soil. Treatment levels to be achieved were 1.0 ppm for PCE and 0.4 ppm for TCE.

8.2.2 Progression of the Remedial Process. With the site believed to be fairly well characterized, the U.S. EPA assigned an engineering/design contractor to develop remedial design (RD) specifications for executing the project in the field. The RD contractor determined that a certain degree of additional field investigation should be carried out in support of the design effort, such as soil sampling to more thoroughly assess the areal extent and depth of the contaminants of concern in the soil, and to collect other site-specific data (such as geotechnical data) that would be relevant and important to the use of a thermal desorption unit at the site. A limited summary of the waste characterization chemical data is presented in Table 8-4.

Table 8-4. AMERICAN THERMOSTAT PROJECT WASTE CHARACTERIZATION DATA

Contaminant	Range of Concentration (ppm)
Organic Compounds	
Trichloroethene (TCE)	ND to 1.1
Tetrachloroethene (PCE)	ND to >10,000
Misc. Other Organic Compounds	ND to 1.0
Inorganic Compounds	
Lead (Pb)	95 to 119
Cadmium (Cd)	1.0 to 1.5

As a result of the RI information and the additional field studies performed during the RD process, the design specifications estimated that as much as 13,000 CY (in-place volume) of contaminated soil might have to be thermally treated by the LTEVF. With a groundwater table as shallow as about 5 ft bgs, this involved treating a combination of unsaturated and saturated soil. Excavation of contaminated soil was to be conducted to bedrock, at about 30 ft bgs. (Note: During excavation, the soil contamination was found to be much more extensive than originally determined, perhaps due to migration of the PCE and TCE via water flushing of the initial source area over the years following the RI. Thus thermal treatment of the soil at American Thermostat was performed in two stages. The initial part, termed “Phase I,” wound up involving nearly 13,000 CY of soil. The subsequent part, termed “Phase II,” resulted in an additional 26,000 CY of soil being treated.)

In-place soil volume was to be used as the basis for payment during thermal treatment, because it offered the following advantages:

- Based on an initial site topographic survey, followed by a post-excavation elevation survey, and area measurements, the actual quantity of soil removed for treatment could be calculated directly and accurately.

- The determination of payment quantity could be made by a third party, such as a licensed Land Surveyor, rather than depending on the thermal desorption vendor's operating staff.

- If, as an alternative, a weigh feed scale was used for determining payment quantities on a per ton basis, the accuracy and calibration of the scale would have needed to be assured regularly.

- Treatment or decontamination of large, contaminated boulders or debris, which were removed incidental to the excavation of contaminated soil, was paid at the same rate as that for treating contaminated soil. Thus, payment for these items was based on their volume, regardless of how, or whether, they were treated or decontaminated.

- Because any treated material that did not pass the thermal desorption treatment test standards was to be re-treated by the thermal desorption vendor, there was no need to try to track failed runs of treated residue from the thermal desorber. Material in this category was reprocessed at the vendor's expense.

The remedial design resulted in a set of technical specifications and several drawings for both Phase I and Phase II. The drawings showed the area on site requiring excavation and treatment; the locations allotted for placement of the thermal desorption facility, waste feed preparation building, treated material staging area, and water treatment facility; and the locations of soil sampling previously conducted. The drawings developed for Phases I and II are included as Figure 8-1 and Figure 8-2, respectively.

In Figure 8-1, the larger area is where shallow excavation was required, defined to be 7 ft bgs. The smaller area is where deep excavation was required, down to bedrock, about 30 ft bgs. As part of the scope of work, the first thermal desorption subcontractor was required to take sidewall soil samples and, in the shallow excavation zone, base samples according to a specified grid arrangement. This sampling was intended to verify what was believed to be the limits of excavation determined during the remedial design. As noted above, this sampling revealed that much more soil beyond the initial limit of 13,000 CY warranted excavation and treatment, which became the subject of Phase II.

In Figure 8-2, the areas of soil excavated and treated during Phase I are indicated for reference as part of the Phase II remedial design. The three new areas overlying the Phase I background define the locations of additional soil requiring excavation and treatment, which were the subject of Phase II.

The technical specifications were developed according to the Construction Specifications Institute (CSI) format and were *performance based* rather than highly detailed (see Appendix H). They did not specify a particular thermal desorption design or technology but instead described some fundamental operating characteristics, such as the minimum throughput and operating capacity factor to be achieved, sampling requirements, and the minimum treatment standards. The intent was to allow the competitive marketplace to determine the appropriate type and size thermal desorption system and the related price. Presuming the site was characterized adequately (although the treatment quantity was underestimated, as described above), the philosophy of the U.S. EPA and their RD contractor was to rely on the experience and expertise of the various thermal desorption service vendors to determine the most suitable thermal system to be used. If the equipment of thermal desorption service vendors cannot execute a project efficiently, the vendors will not pursue the contract.

The list below provides a concise summary of the thermal desorption vendor's scope of work, as provided for by the technical specifications.

- Mobilization and site preparation
- Excavation and shoring and bracing of sidewalls
- Waste feed preparation
- Thermal desorption processing of approximately 13,000 CY (Phase I) and approximately 26,000 CY (Phase II) of PCE- and TCE-contaminated soil
- Backfill of treated soils on site
- Provision and operation of water treatment system
- Demobilization and site restoration.

The thermal desorption vendor was procured for the U.S. EPA by their remedial action (RA) contractor, who held the subcontract and managed the remediation work with a small staff. The thermal desorption subcontractor was responsible for performing all of the actual on-site field work.

To initiate the procurement process, a summary description of the project was placed in the *Commerce Business Daily* (CBD) to alert potential thermal desorption service vendors of the availability of the Request for Proposals (RFP) package. A small charge was imposed to purchase the RFP so that only firms potentially interested in bidding or participating in the project requested the RFP. It was noted in CBD that Bid Bonds would be required with the submittal of proposals, and that Performance Bonds would be required from the successful offeror prior to actual subcontract award. Thus, it was not important at the outset to prequalify bidders who would receive the RFP. Only firms seriously interested in responding to the RFP, and confident that they could perform the work satisfactorily if awarded the project, participated

in the procurement process. Later on, however, as part of the proposal evaluation process, the more limited number of responsive bidders who supplied proposals were scrutinized thoroughly.

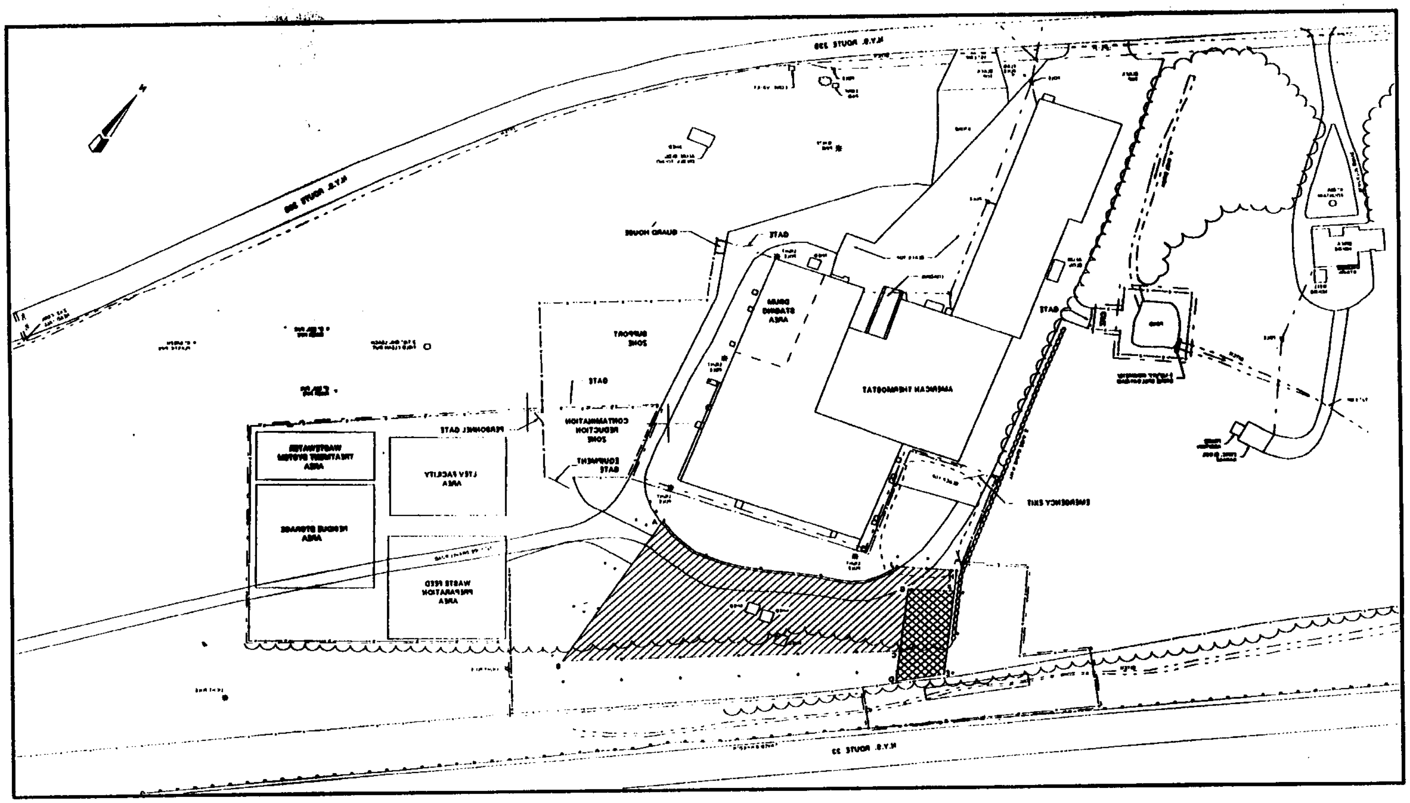


Figure 8-1. American Thermostat Site Phase I Soil Excavation Areas

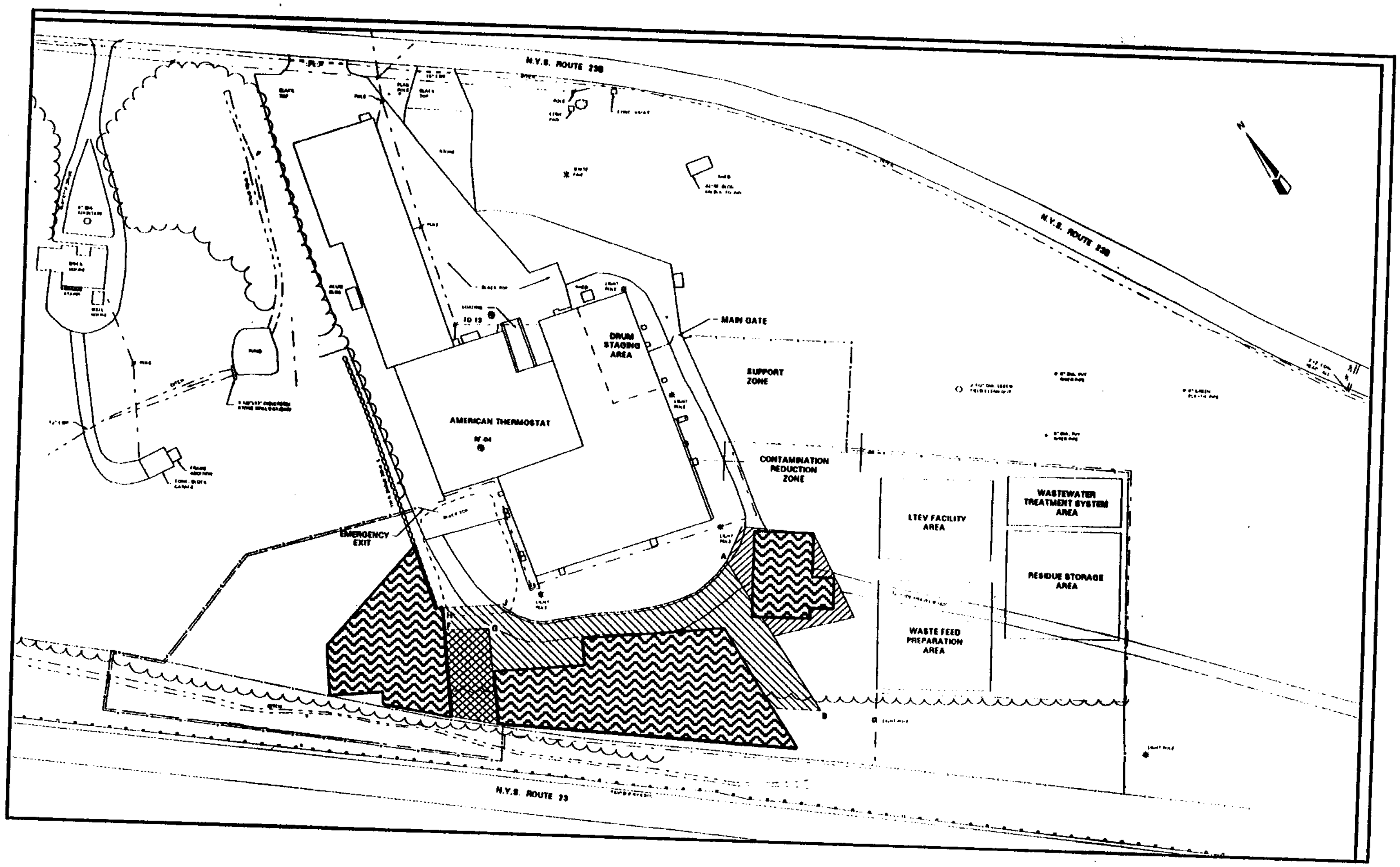


Figure 8-2. American Thermostat Site Phase II Soil Excavation Areas

The RFP package, consisting of the technical specifications and drawings and the commercial terms and conditions that would become part of the subcontract upon award, was distributed to interested potential bidders. A few weeks later, a mandatory pre-bid site meeting with a question-and-answer session concerning the RFP was held. Preliminary responses to questions asked at the meeting were given at the time, but all questions were required to be formally submitted in writing, following the site meeting, and written responses were provided to all bidders shortly thereafter.

The proposal review and evaluation process was conducted according to the discussion and criteria in Section 6.2 of this Application Guide. Because execution of the work required the use of specialized technical equipment in the form of a thermal desorption system, a "best value" determination for subcontract award was preferred over simply awarding the work to the low bidder. In some instances the low bidder may not have adequately understood the scope of work, perhaps due to inexperience, and so awarding that firm the work could have led to a very difficult performance period and an adversarial situation. Alternatively, some firms might have been highly experienced but intentionally may have bid low, expecting that they would succeed in obtaining approval for numerous change orders during performance of the work, based on loopholes they perceived in the technical specifications.

A tabulation of the actual cost data received from bidders in their proposals for Phases I and II of the soil remediation at American Thermostat is summarized in Table 8-5. The total soil quantity bid upon for Phase II is greater than the final actual quantity treated, because the starting basis was a "not to exceed" estimate. For Phase II, the bid quantity was for 30,000 CY but the actual amount of soil treated was about 26,000 CY. These bids were received in late 1992 (Phase I) and mid-1995 (Phase II).

Some important inferences can be drawn from Table 8-5. As additional information, it is noted that all bidders proposed to use direct-contact rotary dryer technologies for Phase I except for bidder D, who proposed to use an indirect-contact thermal screw thermal desorber system. Similarly for Phase II, all bidders planned to use direct-contact rotary dryer thermal desorption systems except for bidder 1, who planned to use batch-feed, heated oven thermal desorption equipment. Only one firm bid both Phase I and Phase II, bidder B and bidder 9.

The fact that nearly all of the bidders intended to use direct-contact rotary dryer thermal desorption systems for both phases of the work attests to the widespread popularity of this technology in the industry, for reasons of versatility, efficiency, and throughput, among others. Even for projects of small to medium size, such as Phase I at 13,000 CY, it is important to complete a project in the shortest reasonable timeframe. The longer a project takes, the greater the cost impact of mounting daily site charges. However, it is disadvantageous to use a unit too large for a particular project. The costs associated with mobilizing/demobilizing it, and the higher capital recovery cost component due to its higher capital cost, would not be offset by a small volume of material. Thus, thermal desorption service vendors have to evaluate whether their equipment is the right size to be competitive.

Table 8-5. AMERICAN THERMOSTAT PROJECT COST INFORMATION (as bid in year shown)

Phase I (1992): 13,000 CY (20,800 tons)							
Bidders	**A**	**B**	**C**	**D**	**E**	**F**	**Avg**
Soil Treatment Cost ($/ton)	$51.74	$68.13	$81.36	$38.75	$91.56	$42.50	**$62.34**
Overall Cost ($/ton)	$181.10	$234.23	$210.96	$214.98	$323.49	$228.17	**$232.16**

Phase II (1995): 30,000 CY (48,000 tons)									
Bidders	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Avg**
Soil Treatment Cost ($/ton)	$52.54	$43.66	$67.44	$33.04	$62.50	$34.38	$36.25	$75.34	$22.81	**$47.55**
Overall Cost ($/ton)	$199.85	$158.20	$230.29	$151.29	$261.82	$135.70	$154.61	$225.63	$172.77	**$187.80**

Table 8-6. AMERICAN THERMOSTAT PROJECT SUMMARY OF THERMAL DESORPTION AWARDS

Phase	Quantity and Cost
Phase I	13,000 CY (20,800 tons) - $3.77 MM Soil Treatment Cost (only) = $51.74/ton
Phase II	30,000 CY (48,000 tons) = $6.54 MM Soil Treatment Cost (only) = $34.38/ton

Although the accuracy of soil treatment costs presented by bidders cannot be verified until project completion, a comparison of the rates in Phase I compared to those for Phase II indicates the economy of scale based on a project of greater soil volume at the very same site. Taking the average unit soil treatment cost values in Table 8-5, as the quantity more than doubled from 13,000 CY to 30,000 CY, the unit cost for thermal treatment declined by nearly 25% from $62.34 to $47.55.

In each case, the soil treatment cost alone represented about 25% of the turnkey (or total project) unit cost for the work. Table 8-6 shows the actual subcontract awards made at American Thermostat for Phase I and Phase II of the soil remediation work.

8.2.2 Transition from Phase I to Phase II. During the latter part of what became known as Phase I of the work, the U.S. EPA found that significantly more soil warranted remediation than was originally planned, perhaps as much as another 30,000 CY. By then, the thermal desorption services vendor for Phase I had smoothed out the operations, after having gone through a lengthy period of adapting to the site conditions. Because the additional quantity was significant, i.e., more than twice the amount in the existing subcontract, a proposal was solicited from the incumbent thermal desorption services subcontractor to perform the work.

8.2.3 Transition from Phase I to Phase II

After several proposals and resubmittals from the subcontractor, it was realized by the U.S. EPA and their RA prime contractor that an equitable agreement on price could not be reached with that vendor. This was significant because, as a public contract conforming to the FARs, it would have been necessary to justify, in detail, the intended sole source multimillion dollar procurement. The outcome was disappointing to all parties because the incumbent vendor was already mobilized there and had progressed along the learning curve to achieve steady operations at the site. The costs of one demobilization and one mobilization could have been saved and the time necessary to conduct a reprocurement to find a new thermal desorption services vendor could have been avoided.

Nonetheless, modified technical specifications and a new commercial section were developed to form a new RFP package, and a reprocurement was conducted. This involved advertising in the CBD and subsequent steps as in the original procurement. Two rounds of "Best and Final Proposals" were requested due to clarification of some price-sensitive issues during the evaluation of the proposals. It took 6 months overall of *apparently* lost time to conduct the reprocurement process. As a result of the reprocurement process, a new thermal desorption service vendor was hired and the project essentially was begun again.

Some favorable consequences occurred, however, that were not completely foreseen. The new Phase II thermal desorption vendor used larger equipment (because he bid a much larger project than Phase I), allowing for significantly greater waste throughput than that achievable by the Phase I vendor. This helped the Phase II vendor to drastically reduce the cost compared to what would have been incurred if the incumbent Phase I thermal desorption vendor had been allowed to continue. A cost savings of approximately $3.5 MM overall resulted from hiring the new Phase II thermal desorption vendor as opposed to retaining the Phase I vendor. Related to this, the *apparent* 6 months of lost time incurred in conducting the reprocurement was recovered because of the Phase II vendor's substantially higher throughput.

8.2.4 Design and Operating Parameters. Table 8-7 summarizes of the type of thermal desorption systems used for each phase of the American Thermostat Superfund project, and some of the key operating parameters.

Table 8-7. AMERICAN THERMOSTAT PROJECT EQUIPMENT AND KEY OPERATING PARAMETERS FOR EACH PHASE

Item	Phase I	Phase II
Quantity of soil treated	20,800 tons	41,600 tons
Feed soil concentrations:		
PCE (Perf. Test)	1126 ppm	66 ppm
TCE (Perf. Test)	non-detect	3.5 ppm
Treated soil concentrations:		
PCE (Perf. Test)	0.033	0.12 ppm
TCE (Perf. Test)	non-detect	0.019 ppm
Treated soil temperature	386^oF	400^oF
Thermal desorber type	direct-contact rotary dryer	direct-contact rotary dryer
Maximum feed rate	22 tons/hr	50 tons/hr
Type of off-gas treatment	thermal oxidizer	thermal oxidizer
Afterburner temperature	1800^oF	1800^oF
Gas cleaning system type	baghouse/wet gas scrubber	baghouse/wet gas scrubber
DRE required	99.99%	99.99%

8.2.5 Lessons Learned from the American Thermostat Project. Several valuable lessons were learned from the overall experience on the American Thermostat Superfund project. Among the most important are the following:

- The transition from Phase I to Phase II demonstrate that it may not always be more economical to extend the scope of an existing thermal desorption subcontractor if the quantity of soil to be remediated changes significantly. Reprocurement of a new vendor may result in significant advantages.

- When developing technical specifications for subcontracted thermal desorption vendor services, it is advisable to explicitly require the vendor’s Project Manager to be resident full time on the project site, from mobilization to demobilization. The person with decision-making authority should be on site to quickly adapt to project variations or repair/modify the thermal desorption equipment due to unforeseen circumstances.

- Critical personnel requirements, such as health and safety staffing, should be specified in detail to prevent the thermal desorption vendor from cutting costs by designating personnel to perform multiple duties, such as asking operations foremen to provide health and safety oversight.

- Whenever possible, regulatory performance criteria should be specified directly in the technical specifications because most regulations are written for high-temperature incineration situations and their applicability to thermal desorption

systems can be subject to interpretation. For example, the minimum DRE that applies to thermal desorption differs from that for high-temperature inceneration.

- In general, the most difficult and important part of executing a thermal desorption project involves material handling and waste feed preparation. If this stage of the work is carried out properly, operation of the thermal desorber should be predictable and reliable.

- Critical deep excavation activities are shoring and bracing system design and installation, and water removal provisions.

- Downtime for thermal desorption systems can be very expensive. The vendor should be required to maintain an adequate supply of spare parts on site.

- Clean make-up water must be available, particularly if a wet scrubber is used to treat the process off-gas. Municipal supply cutbacks during drought conditions should be anticipated.

- Treated residue storage bins should not be oversized. Otherwise, if a bin's inventory fails to meet the treatment standards, more material will have to be re-treated.

- Extreme weather conditions can decrease productivity, greatly affecting the project cost. Extreme cold can limit activity and extreme heat can result in heat stress on staff wearing heavy PPE.

- Much of the staging area for the thermal desorption system need not be OSHA Level C, for health and safety purposes. Typically, only the vicinity of the primary chamber will require Level C PPE.

Section 9.0: IMPLEMENTING A THERMAL DESORPTION PROJECT

Though the actual sequence and scope of the Remedial Action Process must be tailored to site conditions and Navy Environmental Restoration funding priorities, some generalizations can be made in the Preliminary Assessment/Site Investigation and Remedial Investigation/Feasibility Study of a contaminated site. The following briefly outlines the steps for analyzing in detail the nature of the site, contaminants, and potential receptors, determining the regulatory requirements and cleanup objectives of the site, and identifying, analyzing, and selecting the remedial technology for cleaning up the site.

1. The first step in any project is to characterize the site thoroughly. If thermal desorption is being considered, it is important that the characterization investigates the chemical and physical properties needed to evaluate the technology's application. Even if a different remedial technology is selected, the information gathered in this first step will be valuable. Arriving at a preliminary decision to use thermal desorption requires the consideration of issues such as, the availability of space and utility services at the site, the probability for community acceptance, and the likelihood of regulatory acceptance. Once a preliminary decision has been made to use thermal desorption, several steps should be taken to choose the most appropriate design of this technology.

2. The second step is to conduct the first-tier of treatability testing, especially if it is uncertain that thermal desorption will work. Though not always necessary, treatability testing, as described in Section 4.1, will confirm the effectiveness of thermal treatment for the site.   First-tier treatability testing offers the benefit of establishing the optimum temperature and residence time needed to achieve the treatment levels. Small projects using off-site thermal desorption may simply send a representative sample to the thermal treatment facility being considered. Projects involving on-site thermal desorption require the project engineer to develop a treatability study program, procure laboratory services to perform the testing, arrange to have representative samples sent to the lab, and review and evaluate the results. The project engineer may want to witness the actual testing in the lab.

3. The third step is to predict the approximate project cost of installing and operating a thermal desorption system.   Section 5.0 provides information that can assist in comparing the price of a thermal desorption system to approximate costs of alternative remedial technologies. If thermal desorption proves to be cost effective and demonstrated to effectively achieve the necessary treatment levels, it could be judged as the most feasible technology available.

4. The fourth step is to gain formal regulatory acceptance of operating a thermal desorption system at a designated sight. The state regulatory agency determines whether a selected remediation technology for a given site complies with state and federal regulations. The regulator should be inclined to concur if presented with a summary of the site characterization data, the results of the first tier of treatability testing, an interpretation of the relevant regulations, and examples of similar previous projects in the state (if any) or elsewhere that have been successful.

5. The fifth step involves developing performance-based technical specifications for execution of the entire project. The complete scope should be packaged as one contract. Involving two (or more) contractors to oversee distinct phases of the project invites problems.

To ensure good and open competition, the Navy could advertise the upcoming project in environmental trade publications or the CBD. In a public procurement scenario, it may be better *not to* eliminate firms through pre-qualifying criteria in order to eliminate the risk of protests. On the other hand, the Navy could justly pre-qualify only those companies capable of performing the work satisfactorily. Such considerations should be based on criteria such as, past project experience, references and personnel resumes, and financial status as indicated on a Dun & Bradstreet report.

Open advertising for bids allows competitive forces in the marketplace to determine the optimum thermal desorption technology, the ideal throughput, and the best price. Bid specifications should provide the site characterization data and treatability study results, along with certain basic operating characteristics or constraints. For example, a minimum throughput might be stipulated but not a maximum. A not-to-exceed timeframe should be set, even though most of the vendors will be motivated to conclude the project much more quickly for competitive reasons.

Technical specifications do not specify the type of thermal desorption technology to be used, rather the treatment standards to be achieved and any incidental environmental limits or necessary performance characteristics. For example, potential residue treatment requirements or emission standards might apply for gas and liquid discharges or a minimum DRE must be achieved. Vendors offering thermal desorption services will interpret the technical specifications and, through their proposals, inform the Navy if their system will meet the project objectives. After evaluating and comparing the proposals, the Navy will select a vendor that provides the services best meeting the needs of the project.

The procurement process could likely proceed as discussed in Section 6.0. Once a thermal desorption vendor is hired, all required technical reports will be submitted for review by the Navy or by a third-party prime contractor elected by the Navy for construction management services. The submittals detail the plans for implementing a system that meets the performance specifications indicated in the vendor's contract. When key submittals are considered satisfactory, the vendor/contractor will commence site preparation and operation under the direction of a Navy representative.

Section 10.0: SUMMARY

(1) As mentioned in Section 2.0, thermal desorption treatment technology is well suited for many of the remediation projects involving organic chemical contamination found on Naval bases. This physical separation process is capable of treating a wide range of organic contaminants in soil, sludge, sediment, and filter cake. Through the volatilzation of moisture and organics the treated soil retains its physical properties and allows the off-gas to be treated by condensation, collection, or combustion. For many years, the definition of thermal desorption has been controversial and the technology's distinction from incineration has been arguably debated. Some regulators feel that the U.S. EPA definition of this technology is open, unclear and subject to interpretation. Many projects have been delayed and/or cancelled because a system was classified as incineration rather than thermal desorption, and therefore bound by restrictive permitting and operating protocols as well as shrouded by public opposition. Despite this, the effectiveness of thermal treatment as a remediation technology has been well established for many contaminants. Although many factors affect the overall cost of cleanup, the project time and length, and equipment design selection, implementing thermal desorption technology can confidently assure an RPM of achieving desired site cleanup goals.

Thermal desorption technology is divided into continuous and batch processes. Continuous systems are *ex situ* and are further broken down into direct (i.e. rotary dryer) and indirect (i.e. rotary dryer and thermal screw conveyor) fired systems. The batch process systems such as the heated oven and Hot Air Vapor Extraction are *ex situ*, while the thermal blanket and the thermal well are *in situ* systems. Further, this guide categorizes thermal desorption into low temperature processes, 200 to 600°F, and high temperature processes, 600 to 1000°F.

(2) Thorough site characterization is a necessary step in determining the applicability of thermal desorption technology. Section 3.0 outlines important physical and chemical characteristics of the soils that must be investigated prior to considering thermal desorption technology application. They are: soil's chemical composition, soil particle size distribution, waste material composition, bulk density, permeability, plasticity, soil in-place homogeneity, moisture content, heat content, contaminant type/concentration/distribution, halogen content, metals concentrations, and alkali salt content. Other initial factors to consider prior to selecting a thermal desorption system are the heating temperature range, quantity of waste to be treated, allowable timeframe, site considerations/logistics, utility requirements, and generated residuals that will need to be managed and disposed of. Thermal desorption is potentially applicable for the treatment of a wide range of volatile organic compounds, semivolatile organic compounds, and even higher-boiling , chlorinated compounds such as PCBs, dioxins, and furans. Though this technology is not effective or intended for the treatment and removal of materials contaminated with inorganics, soils holding small amounts of heavy metals are expected and taken into consideration. A decision tree, as seen in Section 3.2.4, can be an extremely helpful guide for RPMs in determining if thermal desorption is the appropriate technology for their project.

(3) As discussed in Section 4.0, each thermal desorption treatment process has unique design and performance characteristics that must be weighed when considering a site for thermal treatment. The primary design characteristics to consider when evaluating continuous and batch treatment systems are: maximum soil feed size, maximum contaminant concentrations in feed stream, heat source, treated soil temperature range, feed rate, off-gas treatment system to be used, flue gas cleaning system to be used, required mobilization time, required layout area, batch size, and treatment time. System performance varies by type of unit, site characteristics, and contaminants being treated. Generally, continuous systems have a higher throughput than batch systems and, typically, are more suited to larger projects. However, though waste feed preparation is important for all the technologies, continuous systems have a 2-in. limit on soil feed particle size. Batch systems are not bound by this restriction. Continuous thermal desorption systems are also more suited for contaminants requiring higher treatment temperatures. Batch thermal desorption systems require somewhat less layout area and less time for mobilization, but have longer treatment times.

(4) As described in Section 5.0, significant factors to consider when estimating the cost to install and operate a thermal desorption system are: project planning; project work plans and submittals; regulatory issues and permitting; site layout, preparation, mobilization, and demobilization; system start-up and performance testing; unit treatment cost for a range of quantities; contaminated soil excavation, material handling, processing, and backfill; sampling and analysis; and site restoration. The series of curves shown in Figures 5-1 through 5-3 relate average thermal desorption treatment costs ($/ton) of various systems under given assumptions. These figures can assist an RPM in reaching initial cost estimates for a project. Table 5-3, "Thermal Desorption Treatment Cost Adjustment Factors," helps adjust cost estimates for variations in the assumed parameters used to construct the above figures. Unit treatment costs for thermal desorption systems average between $35-$322 per ton. It is important to note that there is a significant difference between the thermal desorption unit treatment cost and the overall unit (turnkey) cost of the entire remediation project. Depending on the site, the unit treatment cost may be a mere fraction of the overall cost.

(5) Section 6.0 discusses that the majority of environmental remediation projects involving thermal desorption are carried out through turnkey, contracted services. Owning or leasing thermal treatment equipment that requires significant capital outlay, specialized staffing and maintenance, may be limited in its range of applicability, is difficult or costly to transport, is unproven in terms of reliability, and is continually undergoing technological changes and improvements, is <u>not</u> recommended for the Navy. Through the contracting of services, the Navy can select the bid that provides the "best value." In this selection process a vendor's proposal for a project should be weighed upon an unbiased evaluation of certain criteria. Specifically, the vendor's price, technical approach, past experience, and qualifications of key personnel. A carefully constructed Bid Form that conveys adequate scope definition for lump sum pricing and separates project elements into appropriate unit costs will lead to considerable ease in payment administration during execution of the project.

(6) Section 7.0 outlined that regulatory compliance issues as well as designated soil cleanup levels must be observed for site restoration using thermal desorption technology. Prior to implementing the technology, siting regulations, which govern the impact of the equipment in

a particular place, and operational regulations, which impact how the technology will be operated and the various inputs/outputs of the unit, must be considered. CERCLA regulatory issues regarding remedy selection criteria, ARARs compliance, permitting requirements, and federal facilities, as well as RCRA regulations involving regulated wastes, TSDF permitting, and contaminated environmental media, guide and control Naval thermal desorption projects. Unfortunately, federal and state cleanup levels for soil/solid treatment technologies vary from site to site and are continually changing. Therefore, it is crucial that state and local agencies are contacted in the early stages of a project for current regulatory criteria in order to avoid delays and setbacks.

(7) Section 8.0 reviewed two case studies involving recently completed thermal desorption projects. These projects performed at Naval Station Mayport Jacksonville, Florida and the American Thermostat Site South Cairo, New York were excellent case studies of a small petroleum-contaminated soil project and a large site contaminated with chlorinated organics, respectively. The guide discusses each project's background, soil remediation process, treatability testing and sampling, design and operation, test results, decontamination and demobilization, and cost. The lessons learned from these projects will prove to be extremely valuable to RPMs working to implement thermal desorption technology.

(8) As discussed in Section 9.0, the road to a successful project proves to be less treacherous when a number of important initial steps and points are carefully considered and followed. Site characterization, treatability testing, project cost prediction, regulatory acceptance and performance-based technical specifications are crucial aspects requiring significant attention when initiating the remedial action process. Some helpful key points are included in the guide that could assist RPMs during the procurement process, through preparation of project advertisement, establishing bid specifications, and on project execution.

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APPENDIX A

COMPARISON OF

DIRECT-CONTACT THERMAL DESORPTION

TO INCINERATION

A.1 Introduction

The information in this appendix was taken from the Thermal Desorption Applications Manual for Treating Nonhazardous Petroleum Contaminated Soils (Troxler et al., 1994) and was edited to fit this Application Guide. The objective of this appendix is to identify the key differences between direct-contact thermal desorption systems treating nonhazardous petroleum contaminated soils and high temperature incinerators treating RCRA hazardous wastes, state-listed hazardous wastes, or TSCA toxic wastes.

The principal functional difference between a direct-contact thermal desorption system and an incinerator is the degree to which organic compounds are thermally oxidized in the primary thermal treatment unit. Thermal desorbers are designed to heat soils to temperatures high enough to volatize the organic compounds into the flue gas stream. This gas stream is then treated in an afterburner that usually operates in a temperature range of 1,400 to 1,800^{o}F. Incinerators are designed to heat solids to temperatures high enough to oxidize or pyrolyze a high fraction of the organic material in the solid waste feed stream in the primary chamber. The flue gas from the incinerator's primary chamber is then treated in a secondary combustion chamber where remaining organic compounds are oxidized in a temperature range of 1,800 to 2,200^{o}F.

The degree of oxidation or pyrolysis is controlled by the operating temperature and type of atmosphere in the primary thermal treatment device. Thermal desorption systems typically heat soils to a temperature range of between 300 to 1,000°F, although some systems may heat soils as high as 1,200°F. Incineration systems typically heat soils to a temperature range of 800 to 1,650°F. Operating at typical thermal desorption soil discharge temperatures lowers fuel usage, lowers combustion gas flows, reduces the required size of air pollution control equipment, and increases the soil processing rates. Incineration systems operating at higher soil discharge temperatures are able to oxidize solid materials, such as wood and debris, and are able to achieve lower residual levels of organic compounds.

Some types of direct-contact thermal desorption devices operate in an oxidative atmosphere, and others operate in an inert atmosphere. Thermal desorption systems that operate in an oxidative atmosphere generally have gas discharge temperatures that should be below the auto-ignition temperature of most of the compounds that are being treated. Incinerators generally operate in an oxidative atmosphere at temperatures above the auto-ignition temperature of the compounds that are being treated.

The primary technical factors affecting thermal desorber performance are the maximum solids temperature achieved, the maximum gas temperature achieved, and the oxygen content of the purge gas. Because of limitations in these parameters, thermal desorption is not an appropriate technology for treating solid combustible materials such as contaminated wood, rubber, and other types of combustible debris. The ability of thermal desorption systems to achieve low (ppb to low ppm) residual levels of organic compounds is limited by the maximum solids treatment temperature, the residence time at or above that temperature, and the vapor pressure of the specific compound at the soil treatment temperature.

There are a number of differences in types of waste that can be treated, process operating parameters, and mechanical features between thermal desorption systems and incinerators. A summary of these differences is presented in Table A-1.

There are significant differences in the regulatory requirements for incinerators treating hazardous or toxic wastes and thermal desorption systems treating nonhazardous petroleum-contaminated soils. Incinerators treating hazardous wastes are subject to the following RCRA incineration performance and operating standards from 40 CFR Part 264 Subpart O.

- DRE of greater than 99.99% for principal organic hazardous constituents (POHCs) unless the incinerator burns RCRA hazardous wastes with codes F020, F021, F022, F023, F026, or F027.

- DRE of greater than 99.9999% for principal organic hazardous waste constituents (POHCs) if the incinerator burns RCRA hazardous wastes with codes F020, F021, F022, F023, F026, or F027, or if the incinerator burns PCB-contaminated wastes.

- Particulate emissions of less than 0.08 gr/dscf corrected to 7% oxygen.

- Hydrogen chloride (HCl) emission control efficiency of >99% or HCl emissions of less than 4.0 pounds per hour.

- Continuous monitoring of waste feed rate, CO concentration in the stack gas, and combustion temperature, and an indicator of combustion gas velocity.

- Control of fugitive emissions.

- Automatic waste feed cutoffs when operating conditions deviate from permitted limits.

Incineration systems are also subject to state and EPA guidance policies on the control of metal emissions.

Thermal desorption systems treating nonhazardous petroleum-contaminated soil are subject to state and local regulations. Regulatory requirements vary widely from state to state. A summary of requirements for several selected states is presented in Appendix E.

Table A-1. Comparison of Direct-Contact Thermal Desorbers and Incinerators

Characteristic	Thermal Desorber[a]	Incinerator[b]
Primary mode of organic treatment	Separation by volatilization	Destruction by oxidation or pyrolysis
Physical forms of waste processed	Flowable solids, sludges, or sediments	Flowable and nonflowable solids, sludges, sediments, organic liquids, and organic-contaminated aqueous wastes
Maximum organic content of feed	0 - 3% for directly heated systems	Up to 100%
Maximum size of feed	Less than 2 to 3 in.	Depends on feed system. Some systems up to 55-gal drums
Equipment types	Direct-contact rotary dryer, converted asphalt plant dryer, thermal screw, heated oven, direct-contact furnace, in situ heating elements	Refractory-lined rotary kiln, fluidized bed
Soil discharge temperature (^oF)	low temperature: 300^o to 600^oF high temperature: 600^o to $1,000^oF$	800^o to $1,400^oF$
Primary chamber gas discharge temperature (^oF)	500^o to $1,200^oF$	$1,000^o$ to $1,600^oF$
Secondary chamber gas discharge temperature (^oF)	$1,400^o$ to $1,800^oF$ 800^o to $1,250^oF$ (catalytic)	$1,800^o$ to $2,400^oF$
Solid fee rate capacity (tons/hour)	10 to 160 tph	1 to 50 tph
Solids residence time in primary chamber (minutes)	5 to 30 minutes	20 to 60 minutes
Heat source	Natural gas, propane, or fuel oil	Natural gas, propane, fuel oil, or waste organic liquid
Primary chamber refractory lining	None	Yes, refractory brick or castable
Heat time	Less than 1 hour	24 to 48 hours
Solids mixing method in primary chamber	Steel or alloy lifters	Tumbling action as waste moves down kiln, sometimes employs refractory dams as “lifters”
Operating atmosphere in primary chamber	Direct-contact: Oxidative Indirect-contact: Inert	Oxidative or pyrolitic
Primary chamber off-gas treatment type	Direct-contact: Afterburner Indirect-contact: Condenser or activated carbon	Secondary combustion chamber or afterburner
Flue gas cleaning system	Direct-contact: Baghouse (usually) with scrubber (sometimes) Indirect-contact: Condenser, activated carbon, afterburner, catalytic burner	Precipitators, baghouse, wet scrubber, or combination
Soil treatment cost ($/ton)	$25 to $125	$150 to over $1,000
Applicable regulations	State regulations	RCRA (40 CFR Part 264) TSCA (40 CFR Part 761) State hazardous waste regulations

a Nonhazardous petroleum-contaminated soils.
b RCRA hazardous, state hazardous, or TSCA toxic waste.

APPENDIX B

CONTAMINANT CHARACTERISTICS

B.1 Introduction

The information in this appendix was taken from Thermal Desorption Applications Manual for Treating Nonhazardous Petroleum Contaminated Soils (Troxler, et al., 1992) with permission of the EPA and was edited for content and format to fit this Application Guide.

Section 3.0 of the main Application Guide summarized key waste characterization information that should be gathered during screening studies to evaluate the potential use of thermal desorption processes. The objective of this Appendix is to present a more detailed description of contaminant characteristics that influence the use of thermal desorption. Contaminant characteristics can be classified into the following general groups:

- Physical properties
- Chemical properties
- Contaminant concentration.

After the fundamental contaminant characteristics are described, and a discussion is presented relating physical and chemical properties of petroleum contaminants to the petroleum product type.

B.2 Physical Characteristics

B.2.1 Overview

Contaminant physical properties that influence the use of thermal desorption processes include volatility, soil sorption characteristics, aqueous-phase solubility, and thermal stability. The following parameters are used in this report as relative indicators of these physical properties:

• Volatility	Vapor pressure (mm Hg)
	Boiling point (°F)
• Soil absorption	Octanol/water partition coefficient (dimensionless)
• Aqueous solubility	Solubility in water at 77°F (ppm by weight)
• Thermal stability	Autoignition temperature (°F)

Table B-1 describes key chemical property parameters that influence the capability of thermal desorption to treat specific petroleum hydrocarbon compounds. Table B-2 presents a summary of chemical property data for C_4 through C_{20} compounds that are commonly found in petroleum hydrocarbons.

B.2.2 Vapor Pressure

The vapor pressure of a contaminant is the key parameter influencing the rate of thermal desorption. Vapor pressure is the force per unit area exerted by a chemical vapor in equilibrium with its pure solid or liquid at a given temperature. The vapor pressure of a compound increases exponentially as a function of temperature. The higher the vapor pressure, the more volatile the compound and, in general, the easier it is to volatilize out of the soil.

Table B-1. THERMAL DESORPTION APPLICATION FACTORS – CONTAMINANT PROPERTIES

Characteristic	Reason for Potential Impact
<u>Physical Characteristics</u>	
Vapor Pressure	Contaminant vapor pressure and contaminant removal rate increase as soil treatment temperature increases.
Boiling point	Relative indicator for degree of difficulty for volatilizing a specific compound.
Molecular weight	Boiling point temperature generally increases as molecular weight increases, therefore, molecular weight is a good indicator of the degree of difficulty of volatilizing a specific compound.
Octanol/water partition coefficient (K_{ow})	Chemical bonding of organics to soil matrix at low residual organic concentrations (<1 mg/kg).
Aqueous solubility	Potential for leaching soluble components into groundwater, potential for steam stripping of organic contaminants.
Autoignition temperature	Combustion of compounds if concentration in thermal desorber off-gas is above LEL and sufficient oxygen is available to support combustion.
<u>Chemical Characteristics</u>	
Concentration of metals or organics in TCLP extract	Untreated waste may be a RCRA hazardous material if TCLP extract exceeds regulatory limits.
	Treated material may be classified as a RCRA hazardous waste and require stabilization. Most likely contaminant is lead from leaded gasoline.
Concentration of metals	Stack emissions of metals are regulated on a state-by-state basis. Most likely metals contaminants are lead, nickel and vanadium. Waste lubricating oil may contain a variety of metals. Some states also have criteria for maximum allowable concentrations of metals in treated soil.
BTEX	Soil cleanup criteria established by state standards. See Appendix H.

Table B-1 (cont'd)

Characteristic	Reason for Potential Impact
Sulfur	Potential air emissions of sulfur dioxide are generally insignificant. Regulated on a state-by-state basis.
Nitrogen	Concentration of nitrogen oxides in thermal desorption system stack gas are generally below 100 ppmv. However, high nitrogen concentrations in waste may present stack emission concerns. Stack emissions are regulated on a state-by-state basis.
Organic gasoline additives	Residual MTBE concentration is a cleanup parameter in some states.
<u>**Contaminant Concentration**</u>	
Lower Explosive Limit	Maximum concentration of organics in feed material to direct-contact thermal desorbers must be limited to prevent the concentration of organics in the off-gas from exceeding the LEL. Maximum petroleum hydrocarbon feed concentrations for direct-contact thermal desorption systems are in the range of 1 to 4%.
Soil treatment time and temperature	Selection of required soil treatment temperature and residence time to meet soil cleanup criteria established by state standards.
Afterburner auxiliary fuel usage	Increasing concentration of organics in feed soil reduces afterburner auxiliary fuel requirements if an afterburner system is used. High concentrations of organics in feed soil (greater than 2 to 4%) may cause concentration of organics in thermal desorber exhaust gas to exceed afterburner thermal capacity.
Liquid waste disposal costs	Increasing concentration of organics in feed material increases organic liquid waste disposal costs if a condensing-type off-gas treatment system is used.

Table B-2. CHARACTERISTICS OF COMPOUNDS IN PETROLEUM PRODUCTS

Compound	Formula	Molecular Weight	Boiling Point (°F)	Log of Octanol/Water Partition Coefficient (Log K_{ow})	Log Solubility in Water (ppm weight)	Lower Explosive Limit (% volume)	Autoignition Temperature (°F)
n-Butane	C4H10	58	32	NA	1.79	1.9	761
1-Pentene	C5H10	70	86	NA	2.17	1.5	523
Pentane	C5H12	72	97	3.62	1.59	1.4	588
Benzene	C6H6	78	176	2.15	3.25	1.4	1,044
n-Hexane	C6H14	86	156	4.11	1.12	1.1	502
Toluene	C7H8	92	232	2.63	2.73	1.4	997
o-Xylene	C8H10	106	291	3.14	2.34	1.0	867
Ethylbenzene	C8H10	106	277	3.13	2.22	1.0	810
1,2,4-Trimethylbenzene	C9H12	120	336	3.58	1.76	NA	970
Naphthalene	C10H8	128	424	3.45	1.51	0.9	979
1-Methylnaphthalene	C11H10	142	464	3.86	1.45	NA	982
1,4-Dimethylnaphthalene	C12H12	156	514	4.36	1.06	NA	NA
Phenanthrene	C14H10	178	644	4.55	-2.96	NA	NA
Pyrene	C16H10	202	759	5.02	-3.88	NA	NA
Triphenylene	C18H12	228	797	5.20	-4.79	NA	NA
Chrysene	C18H12	228	838	5.91	-5.70	NA	NA
Perylene	C20H12	252	752	5.91	-6.69	NA	NA

NA - Not Available

One report, based on a number of laboratory studies, indicates that the soil temperature required to achieve a commercially viable thermal desorption rate for a contaminant can be predicted from the contaminant's vapor pressure characteristics (check reference). This report indicates that the optimum soil temperature range is that at which the contaminant would exhibit a vapor pressure of between 0.5 and 2.0 atmospheres (380 to 1,520 mm Hg) in a closed system. The boiling point of a compound is the temperature at which the vapor pressure is equal to 1.0 atmosphere (760 mm Hg). Based on the results of the study cited, a vapor pressure range of 0.5 to 2.0 atmospheres is used in this report to compare soil treatment temperature requirements for processing petroleum hydrocarbons by thermal desorption processes.

Temperature has a strong influence on the vapor pressure of a compound, with the vapor pressure increasing exponentially as a function of temperature (Reid et al., 1977). This relationship can be expressed by the Antoine equation as follows:

$$\ln p^* = A - \frac{B}{T + C} \qquad \text{(B-1)}$$

where:

p^*	=	Vapor Pressure (millimeters of mercury)
A	=	Antoine Coefficient (dimensionless)
B	=	Antoine Coefficient B (dimensionless)
C	=	Antoine Coefficient C (dimensionless)
T	=	Temperature (°K)

An extensive compilation of Antoine coefficients for petroleum hydrocarbon compounds is available in the literature (Reid et al., 1977). The Antoine equation was used to calculate vapor pressure curves as a function of temperature for benzene, ethylbenzene, naphthalene, and phenanthrene. These compounds were chosen as examples because their volatility values span a range from very high (benzene) to very low (phenanthrene). These data are presented in Figure B-1. This figure can be used to predict an approximate soil treatment temperature range for a specific compound by following the steps described below:

- Draw horizontal lines at a vapor pressure of 380 mm Hg (0.5 atmosphere) and 1,520 mm Hg (2.0 atmospheres).

- Draw vertical lines at the points where the horizontal lines intersect the vapor pressure curve for a specific compound.

- Read the treatment temperature range at the intersections of the vertical lines and the X axis.

Using the procedure described above, the estimated temperature range for treating phenanthrene by thermal desorption is between 580°F and 720°F. This type of analysis was conducted for all of the compounds listed in Table B-2. The results of these analyses are presented in Figure B-1.

The procedure described above can be used to estimate the treatment temperatures that are required in thermal desorption devices if cleanup criteria are based on residual concentrations of specific compounds. If treatment criteria are based on parameters such as total petroleum hydrocarbons, knowledge of the type of petroleum contaminant type and original distillation temperature is required to assess the required treatment temperature. Treatment temperatures required for specific petroleum products may be estimated from Figure B-2.

B.2.3 Boiling Point

The boiling point of a compound is defined as the temperature at which a compound's vapor pressure equals 1.0 atmosphere (760 mm Hg at sea level). Therefore, boiling point is a relative indicator of the volatility of organic compounds. Boiling point data are readily available in the literature in many chemical engineering handbooks.

The boiling points of petroleum hydrocarbon compounds generally increase with increasing molecular weights. An example relationship, using data from Table B-2, is shown in Figure B-2.

B.2.4 Molecular Weight

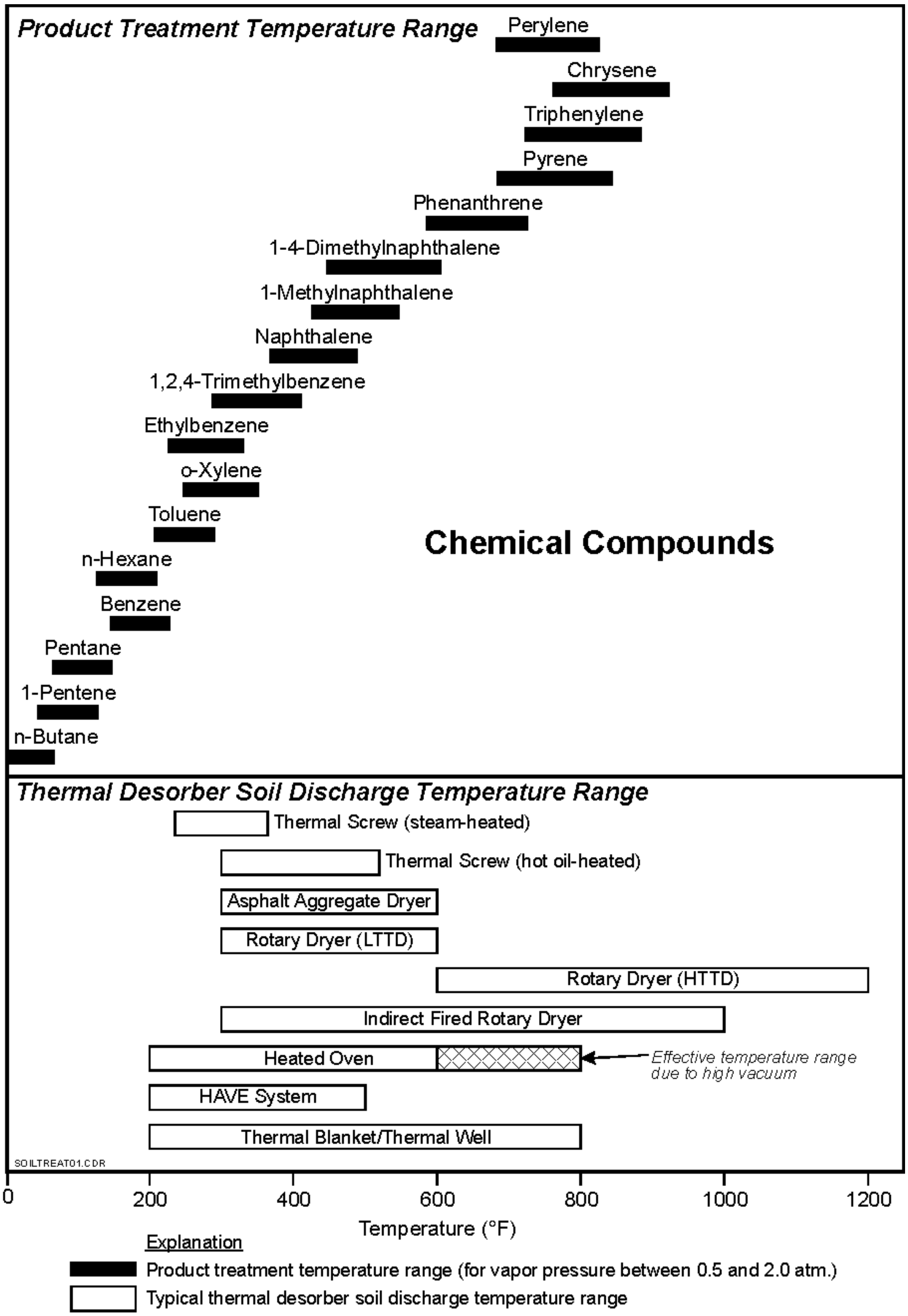
If vapor pressure or boiling point data are not readily available, the molecular weight of a hydrocarbon can be used to approximate the degree of difficulty in treating specific organic compounds by thermal desorption. For example, most thermal desorption devices can heat contaminated soil to a temperature of at least 400°F. If a horizontal line is drawn on Figure B-2 at a value of 400°F, it will intersect the plot of molecular weight data at a molecular weight of approximately 120. Therefore, all hydrocarbon compounds with molecular weights of less than 120 should be readily treated at a temperature of 400°F. Hydrocarbon compounds with higher molecular weights will require correspondingly higher thermal desorption treatment temperatures.

B.2.5 Soil Absorption

The sorption of an organic compound to soil is described by the contaminant's soil sorption coefficient, K_d. Values for K_d are not readily available, so the octanol/water partition coefficient, K_{ow}, can be used as a surrogate parameter (check reference). The octanol/water partition coefficient is a relative indicator of a compound's tendency to partition between a octanol phase and the water phase in an extraction procedure.

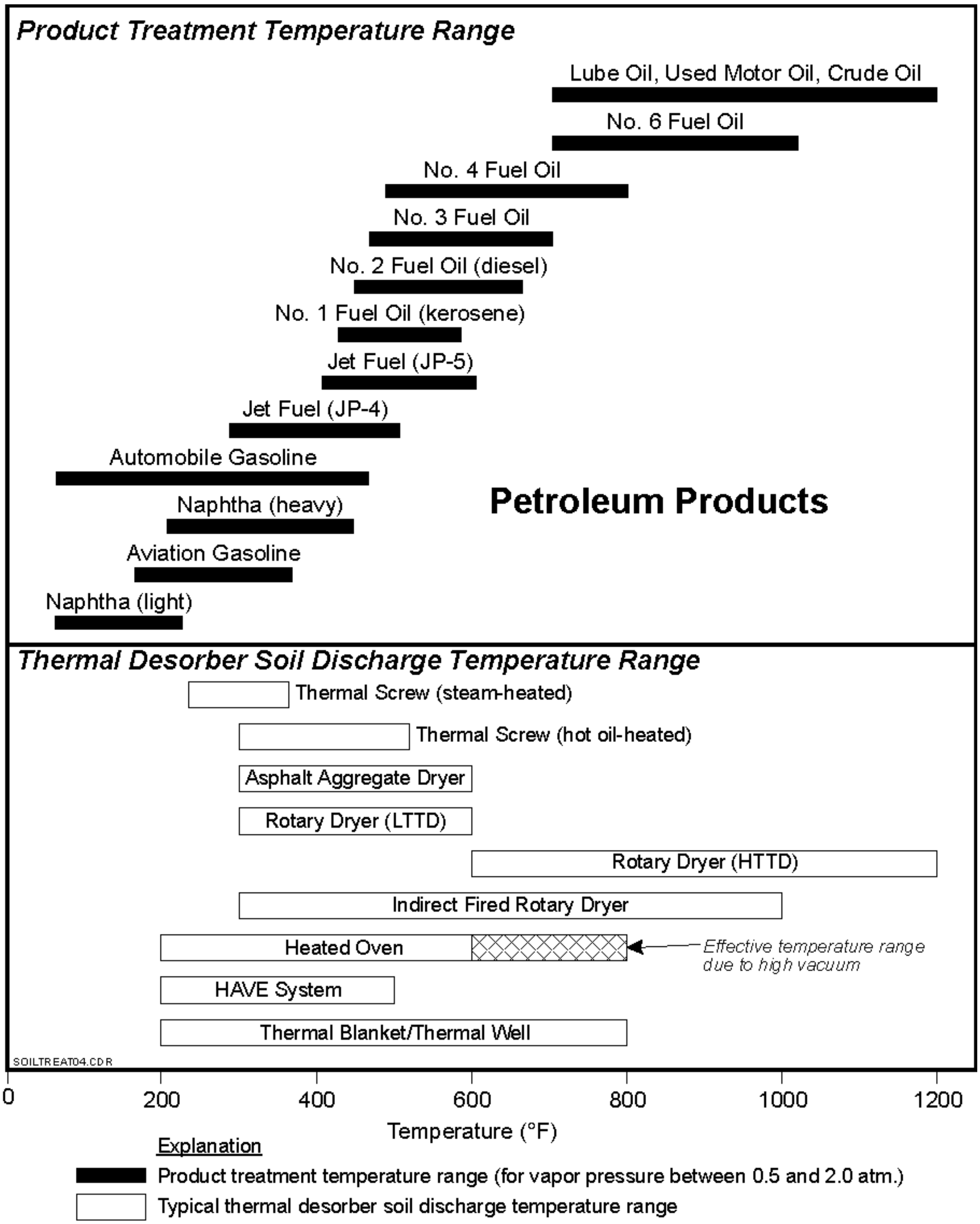
The log of the octanol/water partition coefficient (Log K_{ow}) is a good indicator of the relative tendency of chemicals to absorb to solids (check reference). The higher the Log K_{ow} value, the more likely a chemical is to absorb to solids. Log K_{ow} values are generally inversely related to aqueous-phase solubilities, i.e., compounds with high Log K_{ow} values have low aqueous-phase solubilities (check reference). Therefore, compounds with high Log K_{ow} values will remain absorbed to soils for long periods of time after a spill. They are not readily transported by solubilization into water that percolates through soil at a spill site. Data in Table B-2 also

indicate that Log K_{ow} values increase as boiling points increase. Therefore, compounds that have high K_{ow} values are not likely to evaporate at ambient temperatures.



Source: Adapted from U.S. EPA, 1991, EPA/540/2-91/008

Figure B-1 Soil Treatment Temperatures for Selected Chemical Compounds



Source: Adapted from U.S. EPA, 1991, EPA/540/2-91/008

Figure B-2 Soil Treatment Temperatures for Selected Petroleum Products

Research results for polycyclic aromatic hydrocarbons (PAHs) indicate that strong absorption forces may limit the degree to which a compound can be removed at a specific temperature (check reference). At low concentrations (less than 1 mg/kg), absorption forces binding a compound to a soil particle may be grater than the separation driving force provided by volatilization. Other research results indicate that absorption characteristics influence the rate of desorption and cause a decreased desorption rate for a compound prior to complete removal (check reference).

Log K_{ow} values of petroleum hydrocarbon compounds generally increase with increasing molecular weight.

B.2.6 Aqueous Solubility

The aqueous solubility of a compound determines the extent to which it will dissolve in water. Compounds that are highly soluble are likely to be partially leached from contaminated soils into the groundwater at sites where spills or leaks are relatively old. This weathering process may remove a high percentage of soluble compounds from the contaminated soil at a spill site.

The log of the solubility, in parts per million by weight, is used in this report to describe the solubility of petroleum hydrocarbons. The log of the solubility generally decreases as the molecular weight of hydrocarbons in the same family increases.

Solubility is inversely related to the octanol/water partition coefficient. Therefore, compounds with low solubility in water are more likely to become absorbed to soil particles.

B.2.7 Autoignition Temperature

The concentration of a specific compound in a contaminated soil can be reduced through the mechanism of compound decomposition into lower-molecular-weight fragments. The autoignition temperature (°F) is used in this report as an indicator of thermal stability.

The extent to which thermal decomposition of petroleum hydrocarbons occurs in a thermal desorber is related to the maximum temperature to which the compound is exposed. Data in Table B-2 indicate that autoignition temperatures for this group of compounds are generally above 750°F. This temperature is higher than typical soil treatment temperatures and off-gas temperatures that are achieved in low-temperature thermal desorption systems. Typical soil treatment temperatures in these types of thermal desorption devices are in the range of 300 to 600°F and exhaust gas temperatures are in the range of 300 to 500°F. Therefore, operating temperatures are below the autoignition temperature and these compounds would not be expected to combust. Thermal desorption devices that are constructed of alloy materials and operate at soil or gas discharge temperatures above 600°F are more likely to achieve some partial decomposition of organic compounds.

Autoignition temperature is not strongly related to the molecular weight of the compound.

B.3 Chemical Characteristics

B.3.1 Overview

Petroleum products contain a variety of compounds and elements that may be subject to regulatory requirements under state air laws or state solid waste management regulations. Chemical components of petroleum products that may affect the use of thermal desorption include the concentrations of metals (lead, nickel, vanadium); benzene, toluene, ethylbenzene, and xylenes (BTEX); sulfur; nitrogen; and gasoline additives. Although PCBs are not generally associated with spills of petroleum hydrocarbons, some state regulations require analyses to confirm there are no PCBs present before the soil can be treated as a nonhazardous waste.

B.3.2 Lead

Tetraethyl lead, $Pb(C_2H_5)_4$, was a common fuel additive in gasoline because it was inexpensive and boosted octane ratings. Tetraethyl lead has been phased out of gasoline because of concern over its health effects. Lead is also commonly found in used motor oils at significant concentrations.

Most petroleum-contaminated soils are excluded from being regulated under RCRA as hazardous wastes. One exception to this general exclusion applies to a soil contaminated with leaded gasoline, which may be a hazardous waste because of the toxicity characteristic for lead (D008). If a waste exhibits the toxicity characteristics for lead, the waste must be handled as a hazardous waste.

B.3.3 Nickel and Vanadium

Nickel and vanadium are commonly found in crude oils. These metals are concentrated in the high boiling fractions of petroleum products, such as No. 6 fuel oil and asphalt (check reference). Nickel and vanadium both have high-boiling points over 2,000°F and would not be separated from a soil matrix at thermal desorption operating temperatures. However, stack emissions of these metals could occur as a result of particulate carryover out of the thermal desorber.

Nickel and vanadium are not toxicity characteristic metals under RCRA and are not normally regulated under state solid waste laws. However, some state air toxics laws (e.g., New York) may limit emissions for these two metals.

B.3.4 Benzene, Toluene, Ethylbenzene, and Xylenes

The BTEX compounds are commonly used as a cleanup treatment criteria parameter for thermal desorption processes. Benzene, toluene, ethylbenzene, and xylenes are all relatively volatile as shown on Figure B-1. These compounds are primarily found in petroleum products such as automobile and aviation gasoline. Because of the high volatility of these compounds, they are readily removed from soils by thermal desorption processes to total BTEX concentrations of less than 1.0 mg/kg. BTEX cleanup criteria typically can be achieved by using

thermal desorption devices because soil treatment temperatures in all types of thermal desorption devices are well above the boiling points for these compounds.

B.3.5 Sulfur

Sulfur may be present in crude oil at concentrations ranging from trace to 8% with most crude oils containing from 0.5 to 1.5% (check reference). Sulfur compounds are found in a variety of petroleum products, with the concentration of sulfur rising with increasing distillation temperature of the product. Typical concentrations of sulfur range from 0.05 to 1.0% in No. 2 fuel oil and from 0.4 to 3.5% in No. 6 fuel oil (check reference). Limited data are available regarding sulfur dioxide emissions from thermal desorption processes. However, at thermal desorption operating temperatures, it is unlikely that a significant fraction of the sulfur in the soil will be converted to sulfur dioxide (SO_2).

B.3.6 Nitrogen

Nitrogen-containing compounds normally are found in crude oils at concentrations of less than 0.2% but may be as high as 1.6% (check reference). Compounds containing nitrogen are concentrated in the high-boiling fractions of petroleum products, such as No. 5 fuel oil and asphalt (check reference). Typical concentrations of nitrogen in No. 2 fuel oil are less than 0.1%, and the average concentration of nitrogen in No. 6 fuel oil is 0.3% (check reference).

The primary source of nitrogen oxides in thermal desorber off-gases will be thermal NO_x from conversion of nitrogen in the combustion air. The concentration of nitrogen oxides in the stack gas from a thermal desorption process typically is less than 100 ppm.

B.3.7 Gasoline Additives

Information on gasoline additives is limited because most mixtures are proprietary (check reference). Some additives are polymeric, and some are amine-related compounds. Detergent additives act as surfactants and reduce the surface tension of a liquid. Surface tension is a factor in determining the extent of subsurface migration that will occur following a leak of organic compounds (check reference). As surface tension decreases, compounds are more mobile and tend to migrate away from the spill site.

Methyl-*tert*-butyl ether (MTBE) is a common gasoline additive used to boost octane ratings. MTBE may be present in gasoline at concentrations of up to 8%. A residual level of MTBE is specified as a soil cleanup criterion in some states. MTBE has a boiling point of 131°F and is easily removed from soil by thermal desorption processes.

B.3.8 PCBs

PCBs normally are not associated with petroleum products. However, a number of states require that PCB analyses be conducted before soils are accepted for treatment in a thermal desorption system. If PCBs are present at a concentration of greater than 50 mg/kg, the waste is subject to TSCA regulations.

B.4 Contaminant Concentration

B.4.1 Overview

The concentration of contaminants in the waste material affects thermal desorption devices in several ways:

- Potential to exceed LEL criteria
- Selection of treatment time and temperature requirements
- Impact on auxiliary fuel requirements in afterburners for systems using afterburners
- Impact on organic liquid waste disposal or recycling requirements for systems using condensers for off-gas treatment systems.

B.4.2 Lower Explosive Limit

The maximum concentration of organics that can be treated by a thermal desorption device depends on the gas temperature in the device, the gas flow through the device, the oxygen content in the device, the water content of the waste, and the types of organic compounds that are present. For safety reasons, the concentration of organics in the exhaust gas of devices operating in an oxidizing atmosphere should be limited to less than 25% of the LEL. For most organics, LELs are typically in the range from 1 to 5% by volume. An analysis of the maximum allowable concentration of organics in the feed material must be conducted for each thermal desorption system based on expected values of the process parameters listed above.

Empirical guidelines on maximum allowable organic concentration in the feed material have been established for direct-contact rotary dryers. For these devices, the maximum concentrations of petroleum hydrocarbons in the feed material that can be treated without exceeding the LEL generally are in the range of 1 to 4%.

Systems that operate in an inert atmosphere, such as thermal screws, do not have limitations on the concentrations of organics that can be processed. In an inert atmosphere, the concentration of oxygen is too low (<2% by volume) to support combustion. Thermal screws are commonly used to treat refinery wastes, such as American Petroleum Institute (API) separator bottoms, that have organic concentrations of 50% or higher.

B.4.3 Treatment Time and Temperature

As the concentration of organics increases, the treatment time and/or temperature required to meet a specific residual concentration level also increases.

B.4.4 Afterburner Fuel Usage

One operating objective of thermal desorption devices is to volatilize organic contaminants and exhaust the organic compounds into a downstream collection or treatment system. For systems that use collection devices such as condensers, the organic content of the waste has very little effect on the overall heat balance for the treatment system. For systems that use afterburners, any organic contaminants that are exhausted to the afterburner will have the net effect of reducing auxiliary fuel requirements.

For example, assume a rotary dryer system is operating at the following conditions:

- Soil feed rate, 50 tph
- Soil water content, 15%
- Soil organic content (gasoline) , 1%
- Thermal desorber exit soil temperature, 500°F
- Thermal desorber exit gas temperature, 350°F
- Afterburner exit gas temperature, 1,600°F.

For this set of conditions, the total energy usage (auxiliary fuel plus organics in desorber off-gas) in the afterburner would be approximately 30 MM Btu/hr. At 1% gasoline contamination in the soil, the total heat value of organic vapors that would enter the afterburner would be approximately 18 MM Btu/hr (assuming no oxidation in the thermal desorption device). Therefore, the oxidation of organics desorbed from the soil would supply approximately 60 percent of the total afterburner fuel requirements.

B.4.5 Organics Treatment

Off-gas treatment systems that use condensation systems must collect and dispose of or recycle any organic contaminants that are collected. For example, assume a thermal screw system is treating 10 tph of soil contaminated with 1% organics. In this case, 200 lb/hr of organic contaminant would be vaporized from the soil. In a typical condensation-type air pollution control system, this organic material would be distributed between four possible destinations:

- Condensed as an organic liquid
- Collected on vapor-phase activated carbon
- Collected on aqueous-phase activated carbon
- Exhausted as gas emissions.

The distribution of organics among these four destinations depends on the type of petroleum hydrocarbon being treated and the operating parameters of the air pollution control system.

B.5 Petroleum Product Types

Physical and chemical properties of crude petroleum and various types of petroleum products vary significantly. These variations can be important in assessing the potential use of thermal desorption for a specific remediation application.

Crude petroleum consists of thousands of different compounds (check reference). The chemical and physical composition of crude petroleum varies widely from region to region and even varies with depth in the same production well. Crude petroleum contains compounds with boiling points ranging from less than 100°F to more than 800°F. In order to effectively treat crude petroleum-contaminated material, a thermal desorption device must be able to heat soil to a temperature that is near the boiling point of the least volatile component.

Most petroleum products are produced by distillation processes that take cuts of products over a defined temperature range. The final chemical composition and associated physical and chemical properties of each product depends upon the chemical composition of the crude petroleum, the type and variation of refining operations, product blending practices, and the types of additives that are used. Table B-2 contains a list of key physical and chemical property data for a variety of petroleum products.

Distillation temperature data in Figure B-2 can be compared to soil discharge temperatures of various types of thermal desorption devices to estimate treatability effectiveness. Typical soil discharge temperature ranges for various types of thermal desorption devices are presented on Figure B-2. If the maximum soil discharge temperature of the thermal desorption device equals or exceeds the upper distillation temperature range for a specific petroleum product type, the thermal desorption device has a high probability of success for treating a soil contaminated with that product.

APPENDIX C

SOIL CHARACTERISTICS

C.1 Introduction

The information in this appendix was taken from the Thermal Desorption Applications Manual for Treating Nonhazardous Petroleum Contaminated Soils (Troxler et al., 1992), with permission of the U.S. EPA and was edited for content and format to fit this Application Guide.

Section 3 summarized soil characteristics information that should be gathered to evaluate the potential use of a thermal desorption process. The objective of this appendix is to present a more detailed description of soil physical and chemical characteristics that influence the application of thermal desorption technologies and describe the impact of these factors on the thermal desorption process.

Physical and chemical characteristics of soils influencing the use of thermal desorption and the reasons for potential impacts are listed in Table C-1. A discussion of these factors is presented below.

C.2 Physical Characteristics

C.2.1 Bulk Density. Remedial investigation reports normally present volumetric estimates of quantities of contaminated soils in units of cubic yards (CY). These estimates generally are developed by reviewing the results of analyses from drilling programs and determining the extent of horizontal and vertical contamination. Performance characteristics for thermal desorption systems are determined by material mass flowrates rather than material volume flowrates. Therefore, to convert from soil volume to soil mass, the bulk density must be known.

For example, the amount of energy, expressed in Btus per pound, required to heat contaminated soil to a target treatment temperature is a function of the soil's heat capacity. Similar relationships apply to the moisture and organic components of contaminated soils.

Bulk density values reported during remedial investigations should be determined using an appropriate ASTM Method (D2937, D1556, D2922, or D2167). Bulk density values should be reported on the same basis as the soil volumes; either an in situ (bank) basis or an ex-situ (excavated) basis. Typical in situ bulk densities of soils range from 80 to 120 lb/ft^3. Because of disturbances during excavation, the bulk density of an excavated soil typically ranges from 75 to 90% of the in situ density.

C.2.2 Particle Size Distribution. Soils are commonly classified according to the Unified Soil Classification System (USCS). The basis for the USCS is that coarse-grained soils can be classified according to grain size distributions, whereas the engineering behaviors of fine-grained soils are related primarily to their plasticity. Plasticity characteristics are measured by a set of tests known as the Atterberg limits. Table C-2 presents a description of the major divisions, group symbols, and typical names from the USCS.

The major soil classification divisions in the USCS include (1) coarse-grained, (2) fine-grained, and (3) peat and highly organic soils. Classification of coarse-grained and fine-grained soils is performed using the materials that pass a 75 mm sieve. Materials larger than 300-mm equivalent diameters are termed "boulders," and materials with equivalent diameters between 75 mm and 300 mm are called "cobbles." Coarse-grained soils (silts and clays) have 50% percent or more material that passes a 75 μm sieve. Peat and highly organic soils are classified visually rather than by grain-size distribution. Peat and highly organic soils can be readily identified by color, odor, and spongy feel, and frequently by fibrous texture. Figure C-1 shows the grain size distributions for each of the coarse- and fine-grained USCS categories.

Coarse-grained soils are further subdivided into gravels, gravelly soils, sands, and sandy soils. Coarse-grained soils are generally free flowing and grains do not agglomerate into large particles. During treatment in thermal desorption devices, the surface area of each grain will be exposed to radiant or convective heat without being insulated by agglomerated soil grains. Coarse grain soils have relatively good heat transfer characteristics compared to highly plastic fine-grained soils.

Coarse-grained soils have relatively low moisture absorption capacities and typically drain well. Material-handling properties of coarse-grained soils are only slightly impacted by the moisture content. The materials handling properties of coarse-grained soils primarily depend on their grain size. Large particles, such as gravels, have to be screened out of the soil and/or crushed before soils are processed through some types of thermal desorption devices. The maximum size material that can be handled usually is determined by the minimum clearances in mechanical devices such as conveyors. Figure C-2 compares the degree of difficulty of handling coarse-grained soils based on the USCS soil classifications.

Fine-grained soils include silts and clays with distinctions between subcategories based on plasticity characteristics. The material-handling properties of fine-grained soils are greatly affected by the moisture content. Water affects the interaction between mineral grains and affects their plasticity and cohesiveness as described in Section C.2.3.

One key characteristic of fine-grained soils affecting the application of thermal desorption technologies is the tendency of soil particles to become entrained in a combustion gas. If entrained particulates are not decontaminated in an afterburner, they may be recycled to the thermal desorber. However, this recycle loop reduces the total soil treatment capacity of the system.

The degree of particulate entrainment is a function of the average particle size of the soil, the type of solids transport mechanism present in the thermal desorber, and the gas velocity in the thermal desorption device. Gas velocities in direct-contact thermal desorption devices typically are between 5 and 10 ft per sec, and particulate carryover typically is in the range of 5 to 30% of the feed material. Gas velocities indirect-contact systems typically are in the range of 1 to 3 ft per sec and particulate carryover typically is in the range of 1 to 5% of the feed material.

Direct-contact systems processing fine-grained soils may have to operate at less than the maximum burner firing rates and gas flow velocities to minimize particulate carryover.

Throughput capacities for processing fine-grained soils may be as much as 50% less than the throughput capacity obtainable with coarser grained materials.

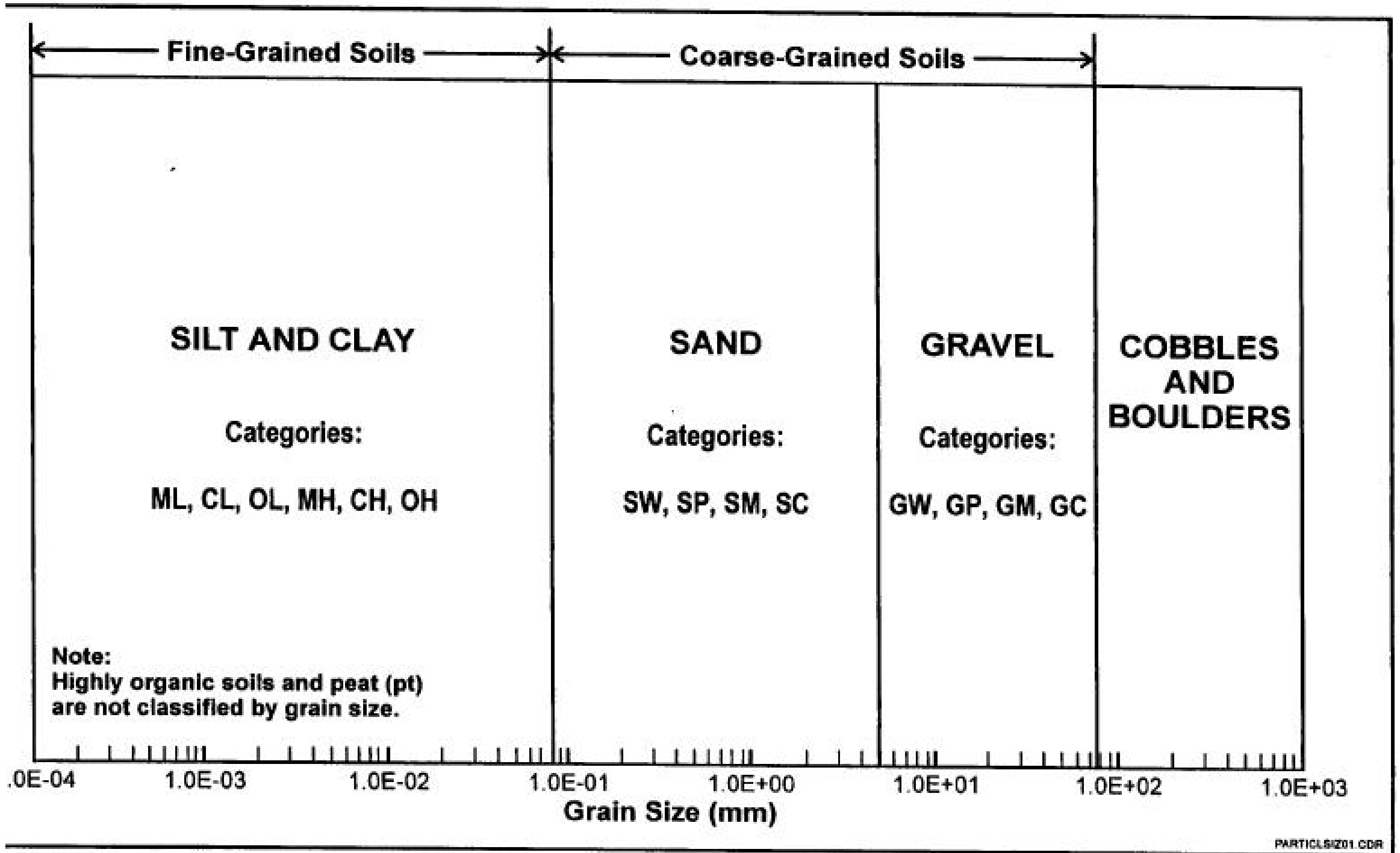
Table C-1. THERMAL DESORPTION APPLICATION FACTORS – SOIL CHARACTERISTICS

Characteristic	Reason for Potential Impact
Physical Characteristics	
Bulk Density	Estimation of soil mass from measured cubic yard quantities.
Particle-size distribution	Type of material screening and size reduction equipment required.
	Material carryover from thermal desorber into off-gas treatment system.
Plasticity	Material sticking to screening, size reduction, and conveying equipment.
	Material sticking to thermal desorber interior surfaces and inhibiting heat transfer.
Heat capacity	Amount of heat that must be transferred to raise soil to target temperature.
Aqueous solubility	Potential for leaching soluble components into groundwater; potential for steam stripping of organic contaminants.
Chemical Characteristics	
Moisture content	Amount of heat that must be transferred to evaporate moisture.
	Increases plasticity of some fine-grained soils.
Concentration of humic material	Analytical interferences from humic material decomposition products.
Metals	State solid waste limitations on metals concentrations.
	State air pollution control regulations on metals in stack emissions.
	TCLP extract concentrations of metals may classify treated material as a hazardous waste.

Table C-2. UNIFIED SOIL CLASSIFICATION SYSTEM CHART

Major Divisions			Group Symbols	Typical Names
Coarse-Grained Soils More than half of material is larger than No. 200 sieve size (75 micron)	Gravels More than half of coarse fraction is larger than No. 4 sieve size (4.75 mm)	Clean Gravels (little or no fines)	GW	Well-graded gravels, gravel/sand mixtures, little or no fines.
			GP	Poorly graded gravels, gravel/sand mixtures, little or no fines.
		Gravels with Fines (appreciable amounts of fines)	GM	Silty gravels, gravel, sand, and silt mixtures.
			GC	Clayey gravels, gravel, sand, and clay mixtures.
	Sands More than half of coarse fraction is smaller than No. 4 sieve size (4.75 mm)	Clean Sands (or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.
			SP	Poorly graded sands, gravelly sands, little or no fines.
		Sands with Fines (appreciable amounts of fines)	SM	Silty sands, sand and silt mixtures.
			SC	Clayey sands, sand and clay mixtures.
Fine Grained Soils More than half of material is smaller than No. 200 sieve size (75 µm)		Silts and clays (liquid limit less than 50)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silty clays of low plasticity.
		Silts and clays (liquid limit more than 50)	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity, organic silts.
Peat and Highly Organic Soils No sieve size criteria			Pt	Peat and other highly organic soils.

Adapted from “An Introduction to Geotechnical Engineering,” 1981, Robert D. Holtz and William D. Kovacs, used with permission of Prentice Hall, Englewood Cliffs, New Jersey.



ce: Troxler et al., (1993)

Figure C-1. USCS Particle Size Ranges

C.2.3 Plasticity Characteristics. Soil plasticity characteristics are measured using a set of parameters known as the Atterberg limits. The Atterberg limits are the water contents at which soils have certain limiting or critical stages in engineering behavior. The Atterberg limits are defined as the moisture contents where soils have the following physical characteristics:

- Liquid limit - lower limit of viscous flow
- Plastic limit - lower limit of plastic state
- Sticky limit - soil loses its adhesion to a metal blade.

Figure C-3 presents a diagram of the physical state of fine-grained soils and the Atterberg limits as a function of soil moisture content. The plasticity index is defined as the range of water content where the soil is in a plastic state and is calculated as follows:

$$PI = LL - PL \qquad \text{(C-1)}$$

where:

PI = Plasticity index (%)
LL = Liquid limit (%)
PL = Plastic limit (%)

The liquidity index is a quantitative value that can be used to assess whether a soil sample will behave as a brittle solid, semisolid, plastic, or liquid. The liquidity index is defined as follows:

$$LI = (Wn - PL)/PI \qquad \text{(C-2)}$$

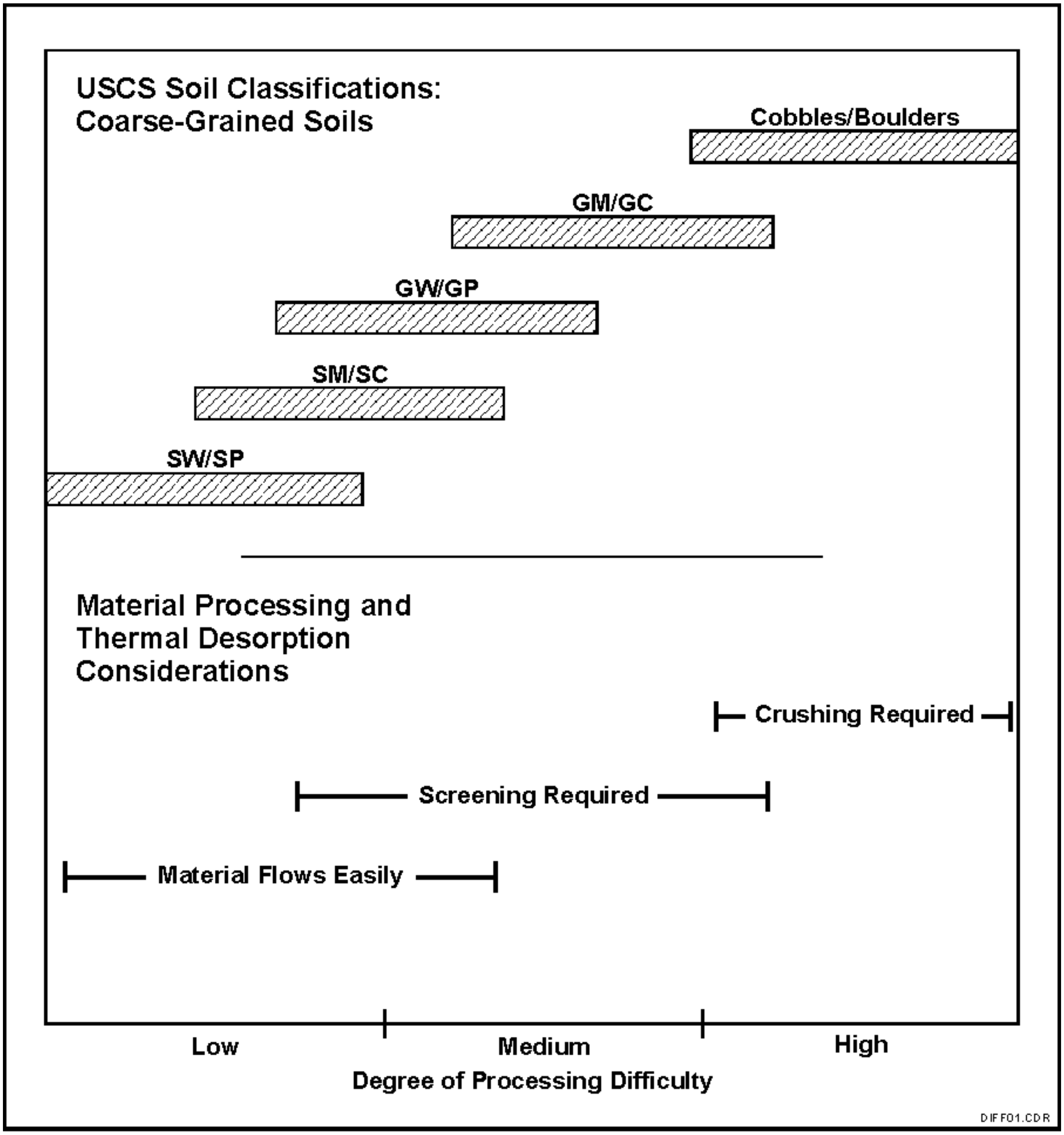
where:

LI = Liquidity index (dimensionless)
Wn = Natural moisture content of soil sample (%)
PL = Plastic limit (%)
PI = Plasticity index (%)

Soils with a liquidity index of less than 0 will behave as brittle solids, whereas soils with a liquidity index between 0 and 1 will behave as plastic materials.

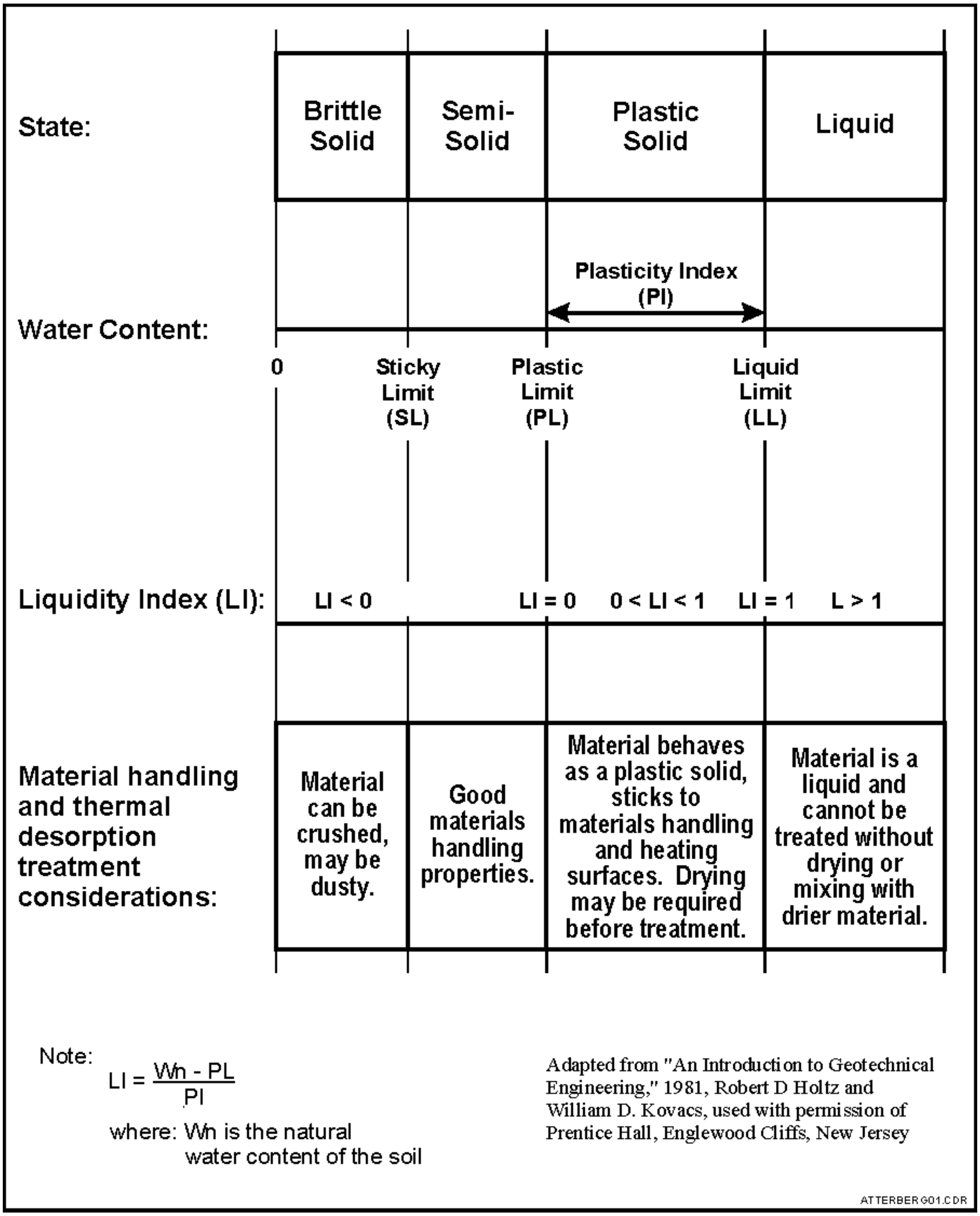
Thermal desorption treatment of a cohesive, fine-grained soil with a moisture content above the plastic limit is extremely difficult. Plastic soils, when subjected to compressive forces, become molded into large particles that are difficult to heat because of low surface area to volume ratios. Soils in a plastic state make it difficult to remove rocks and other debris tend to stick to material-handling equipment, and cause jamming problems. Plastic soils also tend to coat interior surfaces of thermal desorption equipment and reduce heat transfer efficiencies.

Soils that have high dry crushing strengths tend to maintain large agglomerations of particles (>1 in. diameter) as they pass through the thermal desorber rather than breaking up into smaller agglomerations of particles. Heat transfer efficiency is less for large agglomerations of particles than for small agglomerations of particles.



Source: Troxler et al., (1993)

Figure C-2. Degree of Processing Difficulty - Coarse-Grained Soils



Source: Troxler et al., (1993)

Figure C-3. Atterberg Limits Chart

Figure C-4 compares the degree of difficulty of treating various USCS classifications of fine-grained silts and clays. This chart is based on the relative cohesive properties of soils, if they are in a plastic state (LI >0), and on dry crushing strength characteristics, if they are brittle solids (LI <0).

C.2.4 Heat Capacity. The heat capacity of the soil partially determines the quantity of energy that must be supplied to raise the temperature of the soil sufficiently to volatilize organic components. Heat capacities of soils normally range from 0.18 to 0.3 Btu/lb-°F, with typical values in the range of 0.23 to 0.26 Btu/lb-°F. Since the typical range in heat capacity value is relatively small, variations in heat capacity are not likely to have a major impact on the application of a thermal desorption process.

C.3 Chemical Characteristics

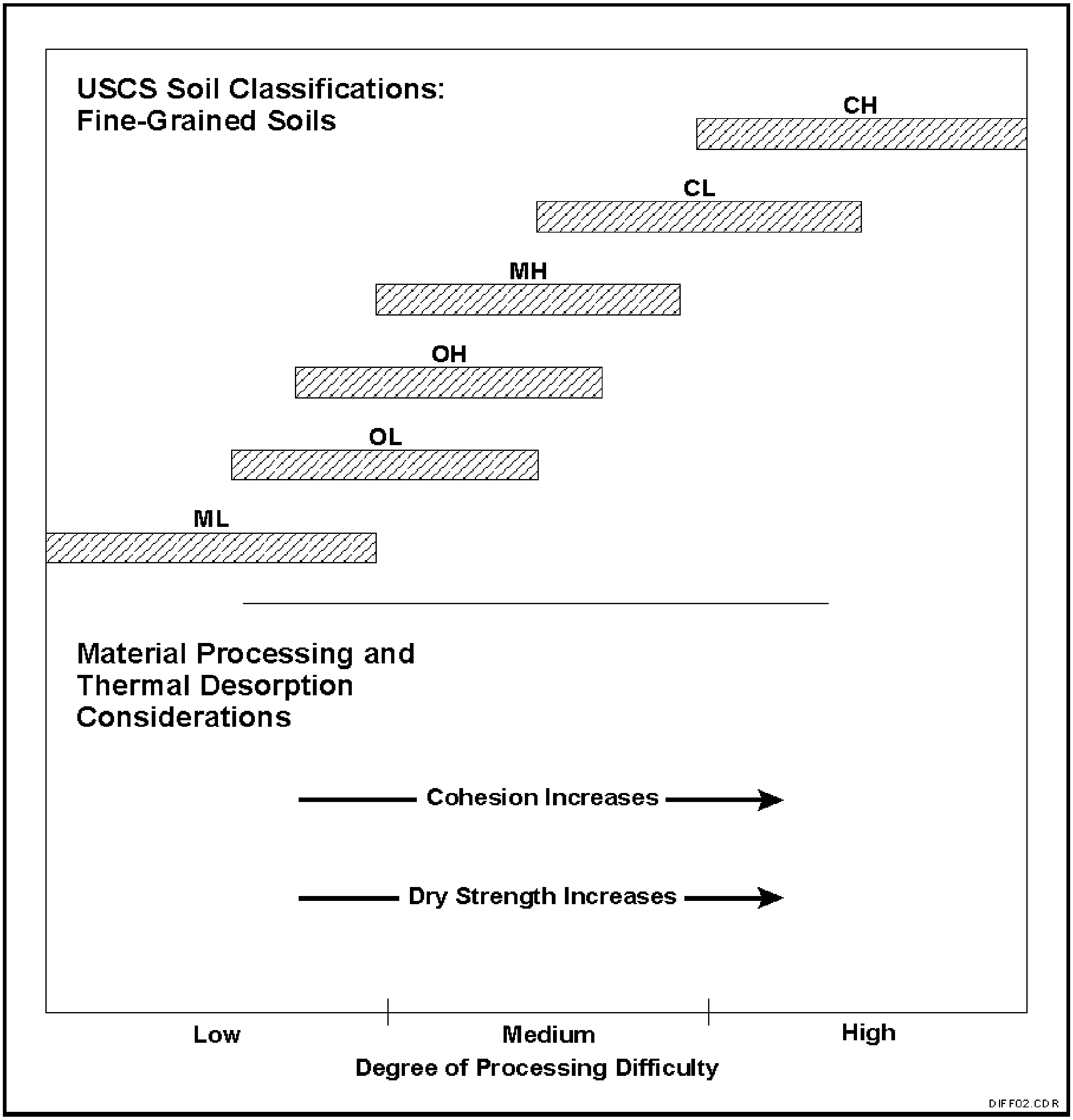
C.3.1 Moisture Content. The moisture content of contaminated soils may range from 5% up to 35% or higher with typical moisture concentrations ranging from 10 to 20%. The moisture may be present either absorbed to the surface of soil particles or chemically bound as a hydrate. Moisture content of a soil will affect both the amount of energy required to heat the soil to the target treatment temperature and the material-handling properties of fine-grained soils as discussed above.

Moisture is a major heat sink in a thermal desorption system treating contaminated soils. Energy requirements as a function of soil moisture content are graphed in Figure C-5. This figure is based on the following assumptions:

- Organic content is 1.0%
- Soil treatment temperature is 650°F
- Thermal desorption device off-gas temperature is 350°F
- Heat capacity of soil is 0.25 Btu/lb-°F
- Heat of vaporization of water is 1,057 Btu/lb
- Heat of vaporization of organic is 380 Btu/lb.

The graph in Figure C-5 indicates that for moisture contents above 10% by weight, moisture is the major heat sink in the system. Soils with 35% moisture require approximately two times as much energy to treat as soils containing 10% moisture. Therefore, the solids processing capacity of a thermal desorption system decreases as the moisture content of the solids increases.

C.3.2 Humic Content. Humic material is naturally occurring organic matter formed by the decay of vegetation. High quality agricultural soils may contain between 5 and 10% organic material. Natural organic material in soil begins to decompose at temperatures above 575°F. Studies of the thermal decomposition of humic materials indicate that pyrolysis products (alkanes, phenols, and PAHs) are formed at 750 to 930°F. Pyrolysis of humic materials also generates carbon monoxide and carbon dioxide.



Source: Troxler et al., (1993)

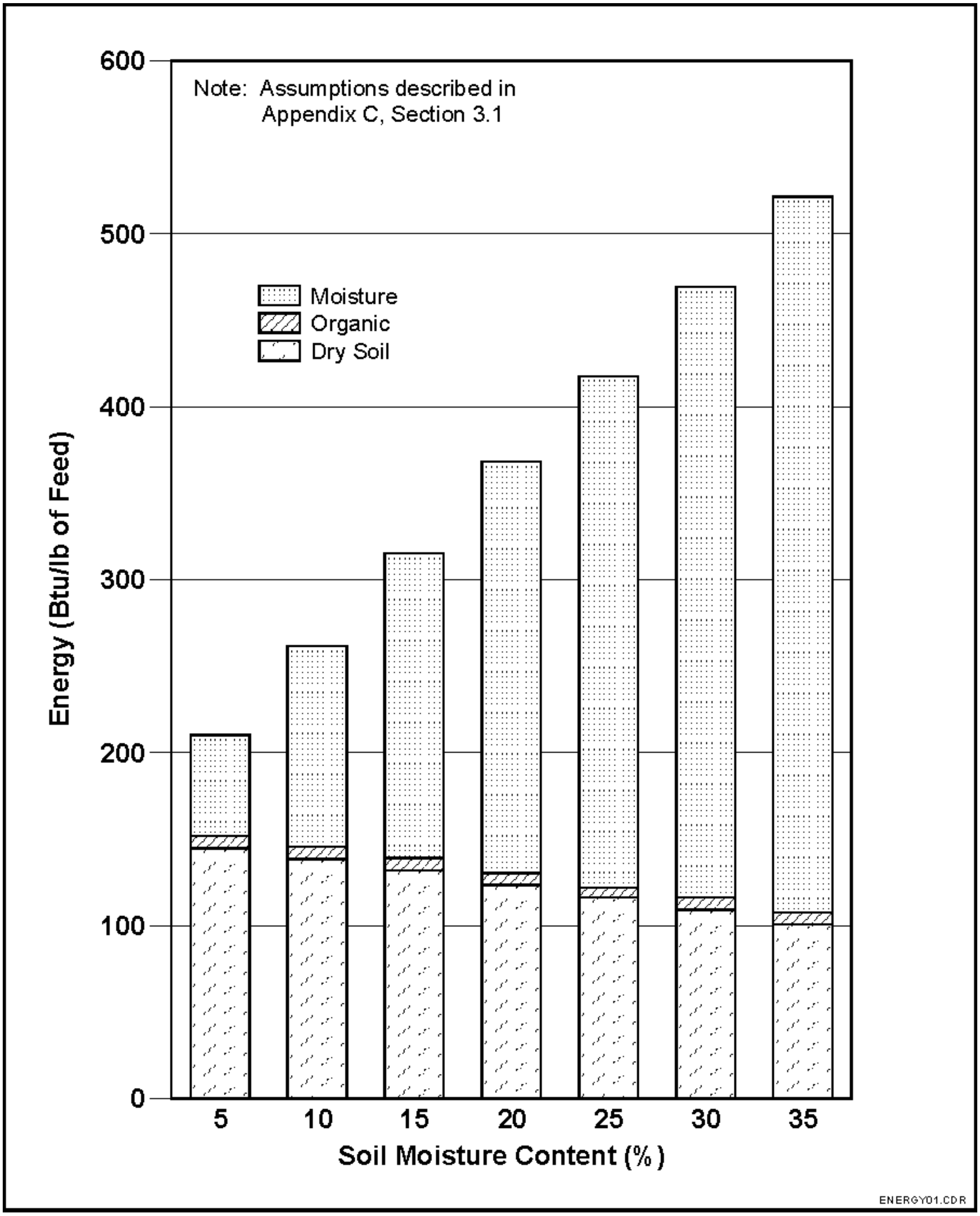
Figure C-4. Degree of Processing Difficulty - Fine-Grained Soils

Soil humic materials can cause analytical interferences in TPH and BTEX analytical tests. Naturally occurring compounds can yield positive values for TPH and BTEX even if there is no petroleum contamination. Peat and highly organic soils have high humic contents, absorb water readily, and may be difficult to dry, requiring high energy input for the thermal desorption system.

C.3.3 Metals. Thermal desorption devices are generally ineffective at separating most inorganic contaminants from a soil matrix. Heavy metals, with the possible exceptions of mercury, arsenic, and lead, are not likely to be significantly separated from soils at thermal desorption operating temperatures. Thermal desorption may be a preferred treatment alternative for soils contaminated with organics and heavy metals, because heavy metals will stay primarily in the treated soil rather than partition to the gas phase.

Research has indicated that soils treated by thermal desorption may exhibit higher concentrations of metals in the extracts from TCLP tests than those found in TCLP extracts from the same soil prior to thermal treatment. This may be attributable to an alteration of the chemical properties of the soil during the heating process, producing a change in the soil's capability to bind metals.

Heavy metals may occur naturally at relatively high concentrations in some types of soils. These background levels may, in some cases, exceed either TCLP criteria for lead or exceed state soil disposal criteria for other metals.



Source: Troxler et al., (1993)

Figure C-5. Energy Demand Versus Soil Moisture Content

APPENDIX D

EXAMPLE THERMAL DESORPTION

HTRW

REMEDIAL ACTION

WORK BREAKDOWN STRUCTURE

D.1 Introduction

The example Work Breakdown Structure (WBS) in this appendix was adapted from the HTRW Remedial Action Work Breakdown Structure developed by The Hazardous, Toxic, Radioactive Waste Interagency Cost Engineering Group in February 1996. These WBS codes were developed for use by the Army Corps of Engineers, Navy, Air Force, Environmental Protection Agency, and the Department of Energy for use on remedial action projects. The complete list of WBS codes was downloaded from the World Wide Web at http://globe.lmi.org/lmi_hcas/wbs.htm and was edited to represent a typical thermal desorption project. The reader is encouraged to access the referenced web site to obtain the complete list of WBS accounts.

D.2 Date Dictionary of Standard Descriptions for HTRW Remedial Action Work Breakdown Structure

This section contains standard descriptions for the HTRW Remedial Action (RA) WBS. A standard description is included for the second (System) and third (Subsystem) levels of the HTRW RA WBS. This “Remedial Action” WBS is intended to be used for all types of RA (construction) contracts for “Remedial Action,” "Emergency Response,” "Rapid Response,” "Immediate Response,” "Interim Remediation,” "Preplaced Remedial Action,” "Removal Action,” “Total Environmental Restoration Contracts (TERCs),” “Disposal,” “Environmental,” and others.

The HTRW RA WBS consists of four hierarchical levels. This document describes Level 2 (System) and Level 3 (Subsystem) under Level 1, Account 331XX “HTRW Remedial Action (Construction).” Further Level 1 breakdown (not included in this document) consists of 332XX “Engineering During Construction” and 333XX “Supervision & Administration (S&A) (Construction Management).” There are 21 Level 2 Systems (331XX 01 through 331XX 22) described, with number 33XXX 16 reserved for future use. Note that because certain activities occur more than once in the WBS, both Levels 2 and 3 must be read and considered in order to select the correct item. Example: Transportation of HTRW to a treatment plant (a Level 3 Subsystem) occurs several times in the RA WBS. In order to make the correct item selection for transportation, Level 2 Systems (where transportation is a Subsystem) must be read and considered.

This document includes the unit of measure (UOM) in both English and metric, and a standard description for each RA WBS item in Level 3 (Subsystem). UOMs assigned to Level 3 characterize Subsystem costs. Standard definitions for Level 4 (Assembly Category) are not included in this document. UOMs for the treatment categories (331XX 11 through 331XX 15) generally indicate the total quantity of material treated (e.g., CY, M3, MGA, KLI, as defined on the following page).

The HTRW RA WBS considers all possible construction items by including the "Other" item at all levels. All items not directly described by the WBS titles are included in the "Other" items as selected by the user (Cost Engineer) for the project estimate. The "Other" items are designated by the number "9X." The user is to replace the "X" with a number, 0 through 9,

and assign an appropriate item description and UOM, but minimize the use of the “Other” 9X items. An operation that is short term and is integral with remedial action or construction activities is to be included in Account 331XX at the appropriate items. For example, to incinerate soil, construction activities include excavation and hauling of contaminated soil to the incinerator, operation of the incinerator, and loading and hauling of the treated material after incineration to a landfill or disposal facility. Another example is a 1 year operational period, which typically is included with the construction contract of projects involving treatment technologies. In such cases, the operation is integral with remedial action construction activities, and thus is included in Remedial Action (Construction) Account 331XX. Operational activities that are long term and are not integral with remedial action are accounted for in a separate document as Account 34XXX.

Please note the following for Data Dictionary:

NOTE 1: For the five-character Account Number (Level 1), the first three characters are from the Army Corps of Engineers Superfund accounting system. The last two characters are user-defined for estimating flexibility.

NOTE 2: Account 32XXX (HTRW Pre Construction and Project Management Activities) includes Project Management, Investigations, and Remedial Design. Account 32XXX is not included in this document.

NOTE 3: Account 33XXX (HTRW Construction Activities) incorporates Remedial Action (including operation during construction), Engineering During Construction (EDC), and Supervision and Administration (S&A) (Construction Management).

NOTE 4: Account 34XXX (HTRW Post Construction and Financial Closeout Activities) includes Post Construction Operation and Maintenance (O&M) and Fiscal/Financial Closeout. Account 34XXX is not included in this document.

NOTE 5: The Superfund and Work for Others Programs use Account Numbers 32XXX, 33XXX, and 34XXX. The DERP (Defense Environmental Restoration Program) and BRAC ER (Base Realignment and Closure Environmental Restoration) Programs use corresponding Account Numbers 72XXX, 73XXX, and 74XXX, which are not included in this document.

NOTE 6: UOM Definitions:

English	Metric
EA - Each	EA - Each
SY - Square Yards	M2 - Square Meters
ACR - Acres	HEC - Hectares
CY - Cubic Yards	M3 - Cubic Meters
LF - Linear Feet	M - Meters
MGA - Thousand Gallons	KLI - Kiloliters
TON - Tons	MT - Metric Tons
MO - Months	MO - Months

English	Metric
HR - Hours	HR - Hours
GAL - Gallons	LIT - Liters
CF - Cubic Feet	M3 - Cubic Meters
LB - Pounds	KG - Kilograms
SF - Square Feet	M2 - Square Meters

D.3 Work Breakdown Structure

The following pages present the table of contents for the table of WBS elements. Each WBS element is described in the table that follows.

TABLE OF CONTENTS
HTRW REMEDIAL ACTION
WORK BREAKDOWN STRUCTURE (WBS)

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX					**HTRW REMEDIAL ACTION** Account 33XXX includes HTRW remedial action (construction) work for all programs and includes operation which occurs during construction (remedial action). Account 33XXX excludes project management at all phases and excludes pre construction investigations and remedial design which are all in Account 32XXX. Account 33XXX excludes post construction Operation and Maintenance (O&M) which is in Account 34XXX.
331XX	01				**MOBILIZATION AND PREPARATORY WORK** Includes all preparatory work required during remedial action or construction. This includes submittals, construction plans, mobilization of personnel, facilities and equipment, construction of temporary facilities, temporary utilities, temporary relocations, and setup of decontamination facilities and construction plant.
331XX	01	01	Each item mobilized	EA (EA)	**MOBILIZATION OF CONSTRUCTION EQUIPMENT AND FACILITIES** Mobilization of equipment and facilities during remedial action is the transport, initial assembly and setup of construction equipment prior to project startup. Work associated with mobilization will include preparation of equipment for transport, equipment transportation and setup, manifests, tolls, permits, escort vehicles, drivers, and equipment operators.
331XX	01	02	Number of personnel	EA (EA)	**MOBILIZATION OF PERSONNEL** Mobilization of personnel during remedial action includes relocation of supervisory personnel and workmen.
331XX	01	03	Each plan	EA (EA)	**SUBMITTALS/IMPLEMENTATION PLANS** Submittal/implementation plans is work incurred during remedial action for obtaining all necessary plans and permits. These include QA/QC plans, work plans, shop drawings, demolition plans, environmental control plans, pollution control plans, site safety and health plans, site security plan, materials handling/transportation/disposal plan and all local, state, and federal permits.
331XX	01	04	Each facility	EA (EA)	**SETUP/CONSTRUCT TEMPORARY FACILITIES** Setup/construct temporary facilities during remedial action includes procurement, setup, and construction of office trailers, storage areas, fencing, access roads, decontamination facilities, decontamination staging areas and other temporary facilities.

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	01	05	Each utility	EA (EA)	**CONSTRUCT TEMPORARY UTILITIES** Temporary utilities are power and lighting, telephone, water, sewer and gas services that will be in place only during construction or remedial action.
331XX	01	06	Each relocation	EA (EA)	**TEMPORARY RELOCATIONS OF ROADS/ STRUCTURES/UTILITIES** Provides for the temporary relocation during remedial action of roads, bridges, buildings, structures and utilities. For re-establishing roads/structures/utilities, see "Re-establish Roads/Structures/Utilities" (331XX.20.03).
331XX	01	08	Each control	EA (EA)	**INSTITUTIONAL CONTROLS** Measures taken during remedial action to protect the public health and safety as an interim action at an HTRW site. This can include such measures as posting warning signs, placing fencing around the site, etc.
331XX	01	09	Each resident or user	EA (EA)	**ALTERNATIVE WATER SUPPLY** Includes providing residents or other users during remedial action with water if the existing water source has been contaminated. This could include providing bottled water or installing a replacement water distribution system, etc.
331XX	02				**MONITORING, SAMPLING, TESTING, AND ANALYSIS** Provides for all work during remedial action associated with air, water, sludge, solids, and soil sampling, monitoring, testing, and analysis. Includes sample taking, shipping samples and sample analysis by on-site and off-site laboratory facilities.
331XX	02	01	Each monitoring station	EA (EA)	**METEOROLOGICAL MONITORING** Meteorological monitoring during remedial action includes measurement of wind, precipitation, and barometric pressure as well as other parameters. Includes the procurement, setup, testing, and operation of meteorological stations and instrument shelters.

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	02	03	Each monitoring event	EA (EA)	**AIR MONITORING AND SAMPLING** Air monitoring and sampling during remedial action is the monitoring for detection of HTRW to ensure compliance with clean air regulations. Includes monitoring of asbestos, HTRW, contaminated dust gases and vapors. See "Asbestos Abatement" (331XX.10.04) for air monitoring during asbestos abatement.
331XX	02	06	Each sample	EA (EA)	**SAMPLING SOIL AND SEDIMENT** Sampling soil and sediment during remedial action includes all work associated with the retrieval of surface and subsurface soil and sediment/sludge samples. This includes any subsurface exploration, split spoon sampling, auger boring samples, the digging of sampling test pits, and shipping to testing lab.
331XX	02	09	Each analysis	EA (EA)	**LABORATORY CHEMICAL ANALYSIS** Laboratory chemical analysis during remedial action consists of work by an independent laboratory for analysis of contaminated samples. This includes air/industrial hygiene analysis, general water and wastewater quality analysis, priority pollutant analysis (all media), biomonitoring and bioassay analysis, Resource Conservation and Recovery Act (RCRA) analysis, miscellaneous waste analysis, and soil and sediment analysis. Does not include storage and disposal of lab samples. See "Off-Site Laboratory Facilities" (331XX.02.14).
331XX	02	11	Each test	EA (EA)	**GEOTECHNICAL TESTING** Geotechnical testing during remedial action consists of work by an independent laboratory for the analysis of soil properties. Included are analysis of shear strength, permeability, consolidation and soil classification.
331XX	02	12	Each Instrument	EA (EA)	**GEOTECHNICAL INSTRUMENTATION** Geotechnical instrumentation during remedial action is used to record measurable changes in soil, surface water and groundwater. Geotechnical instrumentation includes piezometers, inclinometers, settlement gauges, and vadose zone monitors.
331XX	02	9x	Treated Soil Sampling		**OTHER (Use Numbers 90-99)** Includes all monitoring, sampling, testing, and analysis during remedial action not described by the above listed subsystems.

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	03				**SITEWORK** Sitework during remedial action consists of site preparation, site improvements, and site utilities. Site preparation includes demolition, clearing, and earthwork. Site improvements include roads, parking, curbs, gutters, walks, and other landscaping. Site utilities include water, sewer, gas, and other utility distribution. Also includes new fuel storage tanks. All work involving contaminated or hazardous substances is excluded from this system. Storm drainage involving contaminated surface water is included under "Surface Water Collection and Control" (331XX.05). Note that topsoil, seeding, landscaping. and reestablishment of existing structures altered during remediation activities are included in "Site Restoration" (331XX.20).
331XX	03	01	Area of demolition	SY (M2)	**DEMOLITION** Demolition during remedial action is the removal of existing structures, pavements, underground utilities, and other miscellaneous items. Also includes handling, loading, hauling, and landfill dumping fees. Excludes any work involving contaminated or hazardous materials.
331XX	03	02	Total area to cleared and grubbed	ACR (HEC)	**CLEARING AND GRUBBING** Construction during remedial action. Clearing and grubbing is the removal of trees, stumps, vegetation, and other unsuitable organic material. Excludes any work involving contaminated or hazardous materials.
331XX	03	03	Volume of material	CY (M3)	**EARTHWORK** Construction during remedial action. Includes stripping topsoil, excavation, backfill, compaction, fine grading, hauling spoil, importation of borrow material and topsoil. Excludes any work involving contaminated or hazardous materials.
331XX	03	04	Area of surfacing	SY (M2)	**ROADS/PARKING/CURBS/WALKS** Construction during remedial action. Roads/parking/curbs/walks include bituminous, aggregate, and concrete surfacing as well as costs for base courses, geotextile fabrics, curbs and gutters, striping, guard rails, and barricades.

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	03	05	Total length of fence	LF (M)	**FENCING** Construction during remedial action. Includes augering post holes, gate posts, line posts, top rail, fabric, apron, and gates.
331XX	03	06	Total length of distribution	LF (M)	**ELECTRICAL DISTRIBUTION** Construction during remedial action. Includes wire, conduit, fittings, manholes, site lighting fixtures, pole base/foundations, trenching, backfill, testing, transformer, switchgear, aerial distribution, underground distribution, and connection fees. Includes distribution up to the point of connection to the treatment equipment’s main power or control panel. Excludes temporary connections.
331XX	03	07	Total length of distribution	LF (M)	**TELEPHONE/COMMUNICATION DISTRIBUTION** Construction during remedial action. Includes wire, conduit, fittings, manholes, trenching, backfill, testing, and connection fees. Includes distribution up to the point of connection to the treatment equipment’s main power or control device (panel, valve, etc.). Excludes temporary connections.
331XX	03	08	Total length of distribution	LF (M)	**WATER/SEWER/GAS DISTRIBUTION** Construction during remedial action. Includes piping, fittings, valves, manholes, excavation, backfill, and connection fees. Includes distribution up to the point of connection to the treatment equipment’s main control device (valve, etc.). Excludes temporary connections.
331XX	03	10	Total length of distribution	LF (M)	**FUEL LINE DISTRIBUTION** Construction during remedial action. Includes piping, fittings, valves, manhole/valve box, testing, connection fees, excavation and backfill. Includes distribution up to the point of connection to the treatment equipment’s main control device (valve, etc.). Excludes temporary connections.
331XX	03	11	Total length of drainage/subdrainage channels	LF (M)	**STORM DRAINAGE/SUBDRAINAGE** Construction during remedial action. Includes piping, manholes, junction boxes, invert construction, grates, covers, headwalls, flumes, rip rap, excavation, backfill, and testing. Excludes any work involving hazardous or contaminated materials.
331XX	08				**SOLIDS COLLECTION AND CONTAINMENT** Provides for exhuming and handling of solid hazardous, toxic, and radioactive waste (HTRW) during remedial action through excavation, sorting, stockpiling,

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
					and filling containers. Provides for containment of solid waste through the construction of multilayered caps as well as dynamic compaction of burial grounds, cribs, or other waste disposal units. Includes transport to treatment plant.
331XX	08	01	Volume of waste material	CY (M3)	**CONTAMINATED SOIL COLLECTION** Includes the removal during remedial action of solid contaminated soil HTRW waste by front end loader, backhoe, graball, clamshell, dragline or other mechanical means.
331XX	08	02	Volume of waste material	CY (M3)	**WASTE CONTAINMENT, PORTABLE (FURNISH/FILL)** Waste containment includes the procurement of and labor to fill containers during remedial action with solid HTRW wastes. Examples of containers are open top sludge containers, closed top sludge containers, roll-off containers, open head drums, spill containment vessels, spill containment pallets, storage tanks, drum liners, over packs, and lab packs.
331XX	08	03	Volume of waste material	CY (M3)	**TRANSPORT TO TREATMENT PLANT** Transport to treatment plant during remedial action includes equipment, materials and labor for hauling, loading and unloading of solid waste.
331XX	14				**THERMAL TREATMENT** Includes operation (separate items for each subsystem technology) of the plant facility during the remedial action phase, based on the volume of waste material treated, including portable treatment equipment which is charged on a time basis and can be used on more than one project (331XX.14.(01.-07.)). Includes a separate item for the construction of a permanent plant facility, including permanent treatment equipment which is purchased for one project only (331XX.14.50.). Thermal treatment is the destruction of wastes through exposure to high temperature in combustion chambers and energy recovery devices. Several processes capable of incinerating a wide range of liquid and solid wastes include fluidized bed, rotary kiln, multiple hearth, infrared, circulating bed, liquid injection, pyrolysis, plasma torch, wet air oxidation, supercritical water oxidation, molten salt destruction, and solar detoxification. Includes process equipment and chemicals required for treatment. For transportation see "Transport to Treatment Plant" (331XX.05.11, 331XX.06.08, 331XX.08.03 or 331XX.09.04).

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	14	02	Volume of waste material	CY (M3)	**LOW TEMPERATURE THERMAL DESORPTION** Remedial action. Includes fluidized bed, rotary kiln, multiple hearth, infrared, circulating bed, liquid injection, pyrolysis, plasma torch, wet air oxidation, batch, etc. Low temperature thermal desorption (also called Low Temperature Volatilization) heats (directly or indirectly) contaminated media such as soil, sediments, sludges, and filter cakes between 200 - 1000°F, driving off water and volatile contaminants. The volatile contaminants may be burned in an afterburner, condensed to reduce the volume to be disposed of, oxidized, through catalytic oxidation or captured by carbon adsorption beds. Auxiliary equipment includes shredders, conveyors, blowers, fuel system, instrumentation and controls, bag houses, scrubbers, and treated material-handling systems.
331XX	18				**DISPOSAL (OTHER THAN COMMERCIAL)** Includes operation (separate items for each subsystem disposal method) of the plant facility during the remedial action phase, based on the volume of waste material disposed, including portable treatment equipment which is charged on a time basis and can be used on more than one project (331XX.18.(01.-10.)). Includes a separate item for the construction of a permanent disposal facility, including permanent disposal equipment, which is purchased for one disposal facility only (331XX.18.15.). Disposal (Other than Commercial) provides for the final placement of HTRW or ordnance at facilities owned or controlled by the Government. An example would be the disposal of wastes through burial at a DOE nuclear facility or ordnance disposal at DOD facilities. Includes handling, disposal fees, and transportation to the final Destruction/Disposal/Storage facility. Excluded is the transportation to a facility for treatment prior to final disposal. For transportation prior to final disposal see "Transport to Treatment Plant" (331XX.05.11, 331XX.06.08, 331XX.08.03 or 331XX.09.04). Disposal may be accomplished through the use of secure landfills, burial grounds, trench, pits, above ground vault, underground vault, underground mine/shaft, tanks, pads (tumulus / retrievable storage, other), storage buildings or protective cover structures, cribs, deep well injection, incinerator, or other.
331XX	18	01	Volume of waste material	CY (M3)	**LANDFILL / BURIAL GROUND / TRENCH / PITS** Provides for operation of a landfill, burial ground, burial trench, or burial pits during the remedial action phase. For disposal taxes and fees charged between agencies or departments, see "Disposal Fees and Taxes" (331XX.18.22).

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	18	21	Weight of waste material	TON (MT)	**TRANSPORTATION TO STORAGE/DISPOSAL FACILITY** Transport to storage/disposal facility during remedial action includes equipment, materials, and labor for hauling, loading and unloading of solid waste and liquid wastes.
331XX	18	22	Weight of waste material	TON (MT)	**DISPOSAL FEES AND TAXES** Provides for all fees and taxes charged during remedial action for the disposal of wastes. These include fees and taxes charged between agencies, departments, and activities at government facilities.
331XX	19				**DISPOSAL (COMMERCIAL)** Commercial disposal during remedial action provides for the final placement of HTRW at third-party commercial facilities that charge a fee to accept waste depending on a variety of waste acceptance criteria. Fees are assessed based on different waste categories, methods of handling, and characterization. Disposal may be accomplished through the use of secure landfills, burial grounds, trench, pits, above ground vault, underground vault, underground mine/shaft, tanks, pads (tumulus / retrievable storage, other), storage buildings or protective cover structures, cribs, deep well injection, incinerator, or other. Includes transportation to the final Destruction/Disposal/Storage facility. Excludes transportation to a facility for treatment prior to final disposal. For transportation see "Transport to Treatment Plant" (331XX.05.11, 331XX.06.08, 331XX.08.03 or 331XX.09.04).
331XX	19	20	Number of waste containers	EA (EA)	**CONTAINER HANDLING** Provides for all work during remedial action associated with the handling of waste containers for periodic inventory or inspection. Does not include placement of waste into disposal units.
331XX	19	21	Weight of waste material	TON (MT)	**TRANSPORTATION TO STORAGE/DISPOSAL FACILITY** Transport to storage/disposal facility during remedial action includes equipment, materials, and labor for hauling, loading and unloading of solid and liquid wastes.

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	19	22	Weight of waste material	TON (MT)	**DISPOSAL FEES AND TAXES** Provides for all fees and taxes charged during remedial action for the disposal of wastes. These include fees and taxes charged at third-party/commercial facilities.
331XX	20				**SITE RESTORATION** Site restoration during remedial action includes topsoil, seeding, landscaping, restoration of roads and parking, and other landscaping disturbed during site remediation. Note that all vegetation and planting is to be included as well as the installation of any site improvement damaged or altered during construction. All vegetation and planting for the purpose of erosion control during construction activities should be placed under "Erosion Control" (331XX.05.13). Treated soil used as backfill will be placed under "Disposal (Other than Commercial)" (331XX.18). All new site improvements, those not disturbed during construction, are to be included under "Sitework" (331XX.03).
331XX	20	01	Volume of material	CY (M3)	**EARTHWORK** Includes stripping topsoil, excavation, backfill, compaction, fine grading, hauling spoil, importation of borrow material and topsoil during remedial action.
331XX	20	02	Number of markers	EA (EA)	**PERMANENT MARKERS** Provides for the establishment of permanent markers during remedial action.
331XX	20	03	Number of features	EA (EA)	**PERMANENT FEATURES** Provides for the re-establishment during remedial action of pre-existing roads, bridges, buildings, structures and utilities which were in place prior to construction. For temporary relocation of roads/structures/utilities, see "Temporary Relocations" (331XX.01.06).
331XX	20	04	Total area	ACR (HEC)	**REVEGETATION AND PLANTING** Revegetation and planting provides for the complete restoration of areas affected by remedial action construction. This includes fine grading and leveling of topsoil, seeding, mulching, fertilizer, sodding, erosion control, shrubs, and trees.
331XX	20	05	Number of barriers	EA (EA)	**REMOVAL OF BARRIERS** Provides for the removal of all temporary barriers and fencing erected during remedial action construction.

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	20	9x			**OTHER (Use Numbers 90-99)** Includes all site remedial action restoration activities not described in the above listed subsystems.
331XX	21				**DEMOBILIZATION** Provides for all work associated with remedial action plant takedown and removal of temporary facilities, utilities, equipment, material, and personnel.
331XX	21	01	Each facility	EA (EA)	**REMOVAL OF TEMPORARY FACILITIES** Removal during remedial action of temporary facilities includes demobilization and dismantling of office trailers, storage and decontamination facilities, and other temporary facilities.
331XX	21	02	Each utility	EA (EA)	**REMOVAL OF TEMPORARY UTILITIES** Provides for the dismantling and disconnection of project utilities during remedial action including site power and lighting, telephone/communication service, water, sewer, and gas service.
331XX	21	03	Each project	EA (EA)	**FINAL DECONTAMINATION** Final decontamination provides for all work associated with the cleaning and decontamination of equipment and other facilities used for remedial action.
331XX	21	04	Each item mobilized	EA (EA)	**DEMOBILIZATION OF CONSTRUCTION EQUIPMENT AND FACILITIES** Work associated with demobilization of remedial action construction equipment and temporary facilities. Includes transportation, manifests, tolls, permits, escort vehicles, drivers, and equipment operators. Also see " Construction Plant Takedown" (331XX.21.07).
331XX	21	05	Number of personnel	EA (EA)	**DEMOBILIZATION OF PERSONNEL** Demobilization of remedial action personnel includes relocation of supervisory personnel and workmen after project completion.
331XX	21	06	Each submittal	EA (EA)	**SUBMITTALS** Submittals are incurred for obtaining all necessary site clean closure documentation. These include all final reports, punch lists, project acceptance, final QA/QC reports, and As-Built Drawings during remedial action .

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	21	07	Each plant	EA (EA)	**CONSTRUCTION PLANT TAKEDOWN** Construction plant takedown includes dismantling of batch plants, cleaning, disposal of debris, and transport of plant equipment during remedial action.
331XX	21	9x			**OTHER (Use Numbers 90-99)** Includes all remedial action demobilization work not described in the above listed subsystems.
331XX	22				**GENERAL REQUIREMENTS** General remedial action requirements which are not specifically identifiable in the other systems such as indirect, overhead, profit, and other general requirements. This system is OPTIONAL. It may be used to separately show general requirements; however, if it is not used, general requirements must be distributed throughout the other systems.
331XX	22	01	Duration on site	MO (MO)	**SUPERVISION AND MANAGEMENT** Personnel, vehicles, and per diem required for field supervision and management of remedial action work. Also includes personnel at the home office not captured under home office General and Administration (G&A) (331XX.22.12.).
331XX	22	02	Duration on site	MO (MO)	**ADMINISTRATION JOB OFFICE** Personnel, vehicles, travel and per diem, and administrative supplies required for field administration of remedial action work. Also includes personnel at the home office not captured under home office G&A (331XX.22.12.).
331XX	22	03	Duration on site	MO (MO)	**WAREHOUSE, MATERIALS HANDLING, AND PURCHASING** Personnel, vehicles, travel and per diem, supplies and equipment required for field warehouse, materials handling, and purchasing for remedial action work.

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	22	04	Duration on site	MO (MO)	**ENGINEERING, SURVEYING, AND QUALITY CONTROL** Personnel, vehicles, travel and per diem, supplies, equipment, and engineering services required for field engineering, surveying, and quality control/assurance for remedial action work. Also includes personnel at the home office not captured under home office G&A (331XX.22.12.).
331XX	22	05	Duration on site	MO (MO)	**EQUIPMENT MAINTENANCE AND MOTOR POOL** Personnel, vehicles, travel and per diem, equipment, and related items required for field construction equipment maintenance and motor pool for remedial action work.
331XX	22	06	Duration on site	MO (MO)	**FIRST AID, FIRE PROTECTION, TRAFFIC CONTROL, AND SECURITY** Personnel, vehicles, travel and per diem, equipment, and related items for field first aid, fire protection, traffic control, and security for remedial action work.
331XX	22	07	Duration on site	MO (MO)	**HEALTH AND SAFETY** Personnel, vehicles, travel and per diem, protective equipment, personnel protective equipment and clothing, monitoring, training, exams, and related items required for field health and safety for remedial action work.
331XX	22	08	Duration on site	MO (MO)	**TEMPORARY CONSTRUCTION FACILITIES - OWNERSHIP** Ownership or rental for field office trailers, facilities, and related items for temporary construction facilities for remedial action work. Excluded are initial setup or construction of the temporary facilities, which is included in "Mobilization and Preparatory Work" (331XX.01.), and final takedown or removal of the temporary facilities, which is included in "Demobilization" (331XX.21.).
331XX	22	09	Duration on site	MO (MO)	**TEMPORARY CONSTRUCTION FACILITIES - OPERATION** Personnel, vehicles, travel and per diem, supplies, services, and related items for the operation of temporary construction facilities during remedial action work.

ACCOUNT (LEVEL 1)	SYSTEM (LEVEL 2)	SUBSYSTEM (LEVEL 3)	DESCRIPTION OF MEASUREMENT	UOM ENG(MET)	STANDARD DESCRIPTION
331XX	22	10	Duration on site	MO (MO)	**PROJECT UTILITIES** Usage of temporary project utilities during remedial action work. Excluded is the construction of the temporary project utilities, which is included in “Mobilization and Preparatory Work” (331XX.01.), and the removal of the temporary project utilities, which is included in “Demobilization” (331XX.21.).
331XX	22	11	Duration on site	MO (MO)	**MISCELLANEOUS PROJECT EXPENSES** Programs (such as startup programs and craft qualification programs), photographs, videos, air freight, submittals and permits following preparatory work, signs, winterization, inventory, property protection, vehicles, travel and per diem, and other miscellaneous project expenses during remedial action work.
331XX	22	12	Duration on site	MO (MO)	**INSURANCE, INTEREST, AND FEES** Insurance, interest, home office overhead, profit, and bond for remedial action work.
331XX	22	9x			**OTHER (Use Numbers 90-99)** Includes all general requirements during remedial action demobilization work not described in the above listed subsystems.

APPENDIX E

REGULATORY CLEANUP CRITERIA

E.1 Introduction

This appendix was reprinted from the November 1997 issue of *Soil & Groundwater Cleanup* magazine with the permission of the publisher, Group III Communications, Inc. The article presents a summary of the soil cleanup standards (or criteria) for TPH and other petroleum compounds for most states in the United States. It also provides a contact for each state environmental agency if more information is required.

State summaries of soil cleanup standards

By Christine Judge, Paul Kostecki, Ph.D. and Edward Calabrese, Ph.D.

Welcome to the Association for the Environmental Health of Soil's (AEHS)'s eighth annual publication of state-by-state cleanup standards for hydrocarbon contaminated soils and groundwater. We conduct this survey each year in order to keep this useful information current and make it available to environmental professionals.

As in past years, contact people in each of the fifty states provided us with updated information on their regulatory programs. Many of the states' programs have changed or are in the process of changing to Risk-Based Corrective Action (RBCA) approaches. Due to the many variations between states' programs, the format of the summaries has become less standardized in an effort to accurately reflect each state's program. For example, readers should note that, for some states, categories of information no longer appear if the state does not provide that information or require its usage in its regulatory program

While we publish these summaries as a handy reference of cleanup standards and procedures in each state, users should be aware of the limitations of summarizing regulatory programs in a table format and should contact each state for complete information. As in previous years, Connecticut, Colorado and Pennsylvania request that interested parties call for information because their programs are not easily summarized in a table format.

Note: Pennsylvania and Colorado are on the verge of publishing new standards, which were not ready in time for this year's survey. We are pleased to provide readers with summaries for Rhode Island and Arizona this year, which have not been available in previous years.

Telephone interviews with state contacts confirmed the continued move towards adopting RBCA (Risk-Based Corrective Action) approaches to setting cleanup standards. Most states already provide the option to cleanup parties of choosing to determine an alternate cleanup level, under specified conditions, based on a risk assessment of the site. In other cases, the agency in charge has no pre-determined standards and makes determinations solely on a site specific basis, as in the cases of North Dakota, California, Arkansas, and Idaho. Site specific considerations may include topography, geology, proximity to groundwater sources or surface water, setting (industrial, residential, commercial), well locations, land use activities, and type of contaminant(s) present.

Recently, several states, including Florida and Rhode Island, have promulgated cleanup standards based on a RBCA approach but divided up into various pathways, such as direct exposure and leachability, which are reflected in their summaries. Besides Florida and Rhode Island, twelve states reported that they are currently in the process of changing their programs to incorporate RBCA, or developing final rules for their RBCA programs.

Acknowledgements:

The Association for the Environmental Health of Soils (AEHS) wishes to thank our state contacts for their help in updating the information for these summaries and for providing us with information on their rules, regulations, and recent program changes. We greatly appreciate the time and effort they put into working with us to make this information available to readers. Thanks also to Chris Page.

The following states ask that interested parties call for information.

Colorado: For information, call the Technical Assistance Hotline at the Department of Labor & Employment, Oil Inspection Section: (303) 620-4029.

Connecticut: Remediation standard regulations have been adopted that detail remediation requirements for soil and groundwater. Please call the Department of Environmental Protection's Underground Storage Tank Program at (860) 424-3374.

Pennsylvania: New standards are expected by October 1, 1997 but were not available in time for publication in this survey. For information, call the Department of Environmental Protection's Bureau of Land Recycling & Waste Management at (717) 722-5599.

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Summary of Alabama Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number[3]	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH[1]	EPA Method 4030, 9071, 418.1, 5520	*	Any amount	100 ppm	100 ppm**
	BTEX[2]	EPA Method 8020	*	Any amount	**	**
	MTBE[2]	EPA Method 8020	*	Any amount	**	**
Diesel	TPH[1]	EPA Method 4030, 9071, 418.1, 5520	*	Any amount	100 ppm	100 ppm**
	PAH[2]	EPA Method 8100, 8310, 8270	*	Any amount	**	**
	BTEX[2]	EPA Method 8020	*	Any amount	**	**
Waste Oil	TPH[1]	EPA Method 4030, 9071, 418.1, 5520	*	Any amount	100 ppm	100 ppm**
	PAH[2]	EPA Method 8100, 8310, 8270	*	Any amount	**	**
	BTEX[2]	EPA Method 8020	*	Any amount	**	**
	Lead	EPA Method 239.2, 7420, 7421	*	Any amount	Site Specific	Site Specific

[1] TPH analyses are required for closure site assessments. [2] COC (Chemicals of Concern) testing is required for preliminary and secondary investigations only. [3] The department is currently evaluating the allowable test methods and expect changes to be made soon. Please contact the department for the latest requirements.
*Dictated by Method ** Risk Assessment may be used for an alternate corrective action limit.

Note: The ADEM (Alabama Department of Environmental Management) is currently developing a risk-based program. Cleanup levels can vary from the above listed values when a risk-based evaluation is made which can support alternate corrective action levels. The UST program is in the process of developing a risk-based program for alternate corrective action limits at UST release sites.

Contact: Dorothy Malaier, Alabama Department of Environmental Management 334-270-5613

Summary of Alaska Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Gasoline range Organics (C6-C9)	Alaska Method 101*	0.7mg/kg	any amount	Site Specific/ 50-1000mg/kg	Site Specific/ 50-1000mg/kg
	Total BTEX	Alaska Method 101* or EPA Method 8020, 8240, 8260	0.007mg/kg	any amount	Site Specific/ 10-100mg/kg	Site Specific/ 10-100mg/kg
	Benzene	Alaska Method 101* or EPA Method 8020, 8240, 8260	0.007mg/kg	any amount	Site Specific/ 0.1-0.5mg/kg	Site Specific/ 0.1-0.5mg/kg
Diesel	Diesel Range Organics (C10-24)	Alaska Method 102	0.5mg/kg	any amount	Site Specific/ 100-2000mg/kg	Site Specific/ 100-2000mg/kg
	Total BTEX	Alaska Method 101* or EPA Method 8020, 8240, 8260	0.007mg/kg	any amount	Site Specific/ 10-100mg/kg	Site Specific/ 10-100mg/kg
	Benzene	Alaska Method 101* or EPA Method 8020, 8240, 8260	0.007mg/kg	any amount	Site Specific/ 0.1-0.5mg/kg	Site Specific/ 0.1-0.5mg/kg
Waste Oil	Gasoline range Organics (C6-C9)	Alaska Method 101*	0.7mg/kg	any amount	Site Specific/ 50-1000mg/kg	Site Specific/ 50-1000mg/kg
	Diesel Range Organics (C10-24)	Alaska Method 102	0.5mg/kg	any amount	Site Specific/ 100-2000mg/kg	Site Specific/ 100-2000mg/kg
	Residual Range Organics (C25-C36)	Alaska Method 103		any amount	2000mg/kg	2000mg/kg
	Total BTEX	Alaska Method 101* or EPA Method 8020, 8240, 8260	0.007mg/kg	any amount	Site Specific/ 10-100mg/kg	Site Specific/ 10-100mg/kg
	Benzene	Alaska Method 101* or EPA Method 8020, 8240, 8260	0.007mg/kg	any amount	Site Specific/ 0.1-0.5mg/kg	Site Specific/ 0.1-0.5mg/kg

Note: (*) Asterisk indicates samples are preserved immediately with methanol in the field.
All soil standards are in the Alaska Underground Storage Tank Regulations, 18 AAC 78.

Contact: Cynthia Pring-Ham, Alaska Department of Environmental Conservation 907-465-5301

Summary of Arizona Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Notification Level	Cleanup Level[1] Residential	Cleanup Level[1] Non-Residential[2]
Gasoline, Kerosene	TPH	8015 AZ	50 to 80 mg/kg	7000 mg/kg	24,500 mg/kg
Jet Fuel	Benzene	EPA Method 8021A	0.05 mg/kg	47 mg/kg	197 mg/kg
	Toluene	EPA Method 8021A	0.10 mg/kg	23,000 mg/kg	80,500 mg/kg
	Ethylbenzene	EPA Method 8021A	0.10 mg/kg	12,000 mg/kg	42,000 mg/kg
	Total Xylenes	EPA Method 8021A	0.15 mg/kg	230,000 mg/kg	805,000 mg/kg
	1,2-Dichloroethane*	***	****	15 mg/kg	63 mg/kg
	MTBE*	***	****	580 mg/kg	2030 mg/kg
	Benzo(a)pyrene**	***	****	0.19 mg/kg	0.80 mg/kg
	Naphthalene**	***	****	4,700 mg/kg	16,450 mg/kg
	TPH	8015 AZ	50-80 mg/kg	7000 mg/kg	24,500 mg/kg
Diesel, Light Fuel Oils	Benzo(a)pyrene**	Same as gasoline category			
	Naphthalene**	Same as gasoline category			
	1,2-Dichloroethane*	Same as gasoline category			
	MTBE*	Same as gasoline category			
	TPH	Same as gasoline category			
Heavy Fuel Oils	Benzo(a)pyrene**	Same as gasoline category			
	Naphthalene**	Same as gasoline category			
	TPH	Same as gasoline category			
Waste Oil[3]	BTEX	Same as gasoline category			
	VOCs[4]	EPA Method 8021A for 8021 AZ-listed analytes	****	****	****
	Benzo(a)pyrene	Same as gasoline category			
	Naphthalene	Same as gasoline category			
	TPH	Same as gasoline category			

Note: Arizona allows the choice of pre-determined standards (residential and non-residential) or risk assessment developed standards (residential and non-residential).

[1]Risk assessment option exists. Protection of groundwater and surface water may require more stringent levels. [2]Choice of cleanup to non-residential standards requires filing a Voluntary Environmental Mitigation Use Restriction (VEMUR) on property title with County Recorder. [3] Initial analyses for BTEX, VOCs and PAHs are only required for the soil samples with the highest TPH concentration. Call the department for information on cleanup levels for VOCs and PAHs not listed in the table above. [4]When VOC analyses are applicable, measure for the presence of the list of analytes for EPA Test Method 8021A.

*Measure for these or other specific petroleum additives when suspected. **Except in the case of waste oil releases, analyses for PAHs are only required in soils where TPH concentrations are below the non-residential cleanup level for TPH, unless a risk assessment is to be performed. ***Contact ADHS (Arizona Department of Health Services) for applicable analytical method(s). **** Contact the department for information.

Contact: Michele Robertson, Arizona Department of Environmental Quality (602) 207-4415

Summary of Arkansas Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Cleanup Level
Gasoline	BTEX*	8020, 8240/8260	Site Specific***
Diesel	PAH's	8100, 8310, 8250/8270	Site Specific***
Waste/Used Oil	PAH's**	8100, 8310, 8250/8270	Site Specific***

* Analysis for gasoline additives must be performed where possible or suspected. (total lead, MTBE, Ethanol/Methanol, EDB, etc.)
** VOC scan may be required where contamination by chlorinated or other solvents is possible or suspected. TCLP for metals may be required at the discretion of the case manager.
*** Clean-up requirements will be site-specific, after consideration of risk according to the ASTM or other accepted risk assessment protocol.
Note: Hydrocarbon remediation program for both soil and groundwater is now based on ASTM, E 1739

Contact: James Atchley, Arkansas Department of Pollution Control & Ecology 501-682-0972

Summary of California Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	DHS Recommended	*	any amount	**10 to 1,000ppm	Site Specific
	***Toluene	EPA Method 8020	5ppb	any amount	**NA to 50ppm	Site Specific
	***Xylene	EPA Method 8020	15ppb	any amount	**NA to 50ppm	Site Specific
Diesel	TPH	DHS Recommended	10ppm	any amount	**100 to 10,000ppm	Site Specific
	BTEX same as Gasoline above. →					

* Test Specific. ** There are three action levels associated w/ TPH & BTEX for sites which fall into categories low, medium and high.
*** If BTEX levels are detectable, even though TPH concentration is below 10ppm gas or 100ppm Diesel, proceed from site investigation to the general risk appraisal. **Note:** California does not have state standard cleanup levels. Values shown are recommended action levels from the LUFT manual. Cleanup levels are site specific. California has 9 Regional Water Quality Control Boards throughout the state and 104 local agencies. The Regional Water Quality Control Board is generally the lead on complex unauthorized UST released, ground water cases and cases referred to them by the local agency. Larger implementing local agencies with staff, expertise, and Regional Water Quality Control Board concurrence may be the lead in overseeing corrective action to these cases. The jurisdiction or Regional Water Quality Control Board enforces site specific cleanup levels, detection levels, etc. If groundwater is contaminated, often times, drinking water standards or MCL's are imposed. Notification is required for all unauthorized releases unless the operator is able to clean up the release within 8hrs, it did not escape from a secondary containment, does not increase hazard of fire or explosion and did not deteriorate secondary containment of UST.
Note: Report any amount which escapes secondary containment, or from primary containment if no secondary containment exists, increases the hazard of fire or explosion or causes deterioration of secondary containment.

Contact: Diane Trommer, California State Water Resources Control Board 916-227-4337

Note: The State of Delaware is currently developing a Risk Based Corrective Action (RBCA) Program, scheduled to be implemented in March 1998. Changes are anticipated. Please call the contact below for updated information after that date.

Summary of Delaware Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level*	Cleanup Level*
Gasoline	TPH	Mod 8015, Mod 418.1 EPA Method 9071	40 mg/kg	any amount	100 ppm	Site Specific generally≤100
		APHA Methods 5520E/ 5520C, 503B, 503E	40 mg/kg	any amount		Same As Above
		California Method GC–FD or TPH-GRO	10 mg/kg	any amount		Same As Above
	BTEX	EPA Method 3010/8020, 5030/8020	1 mg/kg	any amount	BTEX>10ppm B>1ppm	Site Specific generally≤10 BTEX, 1 B
		EPA Method 3810, 8240, 8240 purge & trap, Mod 602	1 mg/kg	any amount		
Diesel	TPH	as above or TPH-DRO	as above	any amount	1000 ppm	Site Specific generally≤1000
Waste Oil	BTEX	as above	as above	any amount	BTEX>10ppm B>1ppm	Site Specific generally≤10 BTEX, 1 B
	TPH	as above	as above	any amount	1000 ppm	Site Specific generally≤1000ppm

* Class B Site. **Note:** Class A sites—more sensitive, more stringent. Class B sites—average sensitivity. Class C sites—less sensitive, less stringent. Sites are rated by the DE DNREC as either A, B, or C. Factors influencing ratings include well locations, groundwater depth, residential, commercial or industrial settings, etc.

Contact: Patricia M. Ellis, Ph.D., Delaware Department of Natural Resources & Environmental Control 302-323-4588

Summary of Florida Cleanup Standards for Hydrocarbon Contaminated Soil

Parameter/ Constituent	Lab Test Protocol & Number	Cleanup Level: Direct Exposure (mg/kg) Residential Use	Direct Exposure (mg/kg) Worker/Industrial Exposure	Leachability (mg/kg) (based on 4 different criteria levels): a	b	c	d
Acenaphthene	***	2300	22000	4	0.6	0.6	40
Acenaphthylene	***	1100	11000	22	0.003*	0.003*	220
Anthracene	***	19000	290000	2000	0.3	0.3	20000
Benzo(a)anthracene	***	1.4	5.1	2.9	0.4	0.4	29
Benzo(a)pyrene	***	0.1	0.5	7.8	1.2	1.2	78
Benzo(b)fluoranthene	***	1.4	5	9.8	1.5	1.5	98
Benzo(g,h,i)perylene	***	2300	45000	13000	2	2	130000
Benzo(k)fluoranthene	***	15	52	25	1.5	1.5	250
Chrysene	***	140	490	80	0.5	0.5	800
Dibenzo(a,h)anthracene	***	0.1	0.5	14	2.2	2.2	140
Fluoranthene	***	2800	45000	550	0.4	0.4	5500
Fluorene	***	2100	24000	87	9.4	9.4	870
Indeno(1,2,3-c,d)pyrene	***	1.5	5.2	28	4.3	4.3	280
Naphthalene	***	1000	8600	1	1	1.3	10
Phenanthrene	***	1900	29000	120	0.02*	0.02*	1200
Pyrene	***	2200	40000	570	0.8	0.8	5700
Benzene	EPA Method 8020, 8021	1.1	1.5	0.007	0.007	0.5	0.07
Ethylbenzene**	EPA Method 8020, 8021	240	240	0.4	0.4	7.7	3.8
Toluene	EPA Method 8020, 8021	300	2000	0.4	0.4	4.8	4
Total Xylenes**	EPA Method 8020, 8021	290	290	0.3	0.3	5.3	2.9
1,2-dichloroethane	Not Required	0.6	0.9	0.02	0.02	0.7	0.2
MTBE	EPA Method 8020, 8021	350	6100	0.2	0.2	150	1.6
TRPHs	Not Required	350	2500	340	340	340	3400

Note: The detection limits shall meet the specified cleanup target levels. Values rounded to two significant figures if greater than 1 and to one significant figure if less than 1.

* Unless the Method Detection Limit (MDL) using the most sensitive and currently available technology is higher than the specified criterion. ** Direct Exposure values based on Soil Saturation Limit (Csat). *** EPA Method 8100, 8250, 8270 or 8310

[1] Testing for all parameters is required for all petroleum contaminated sites initially. Some parameters may be discontinued if not initially detected, with the concurrence of the department.

a Table V - Groundwater Cleanup Target Levels for Resource Protection/Recovery.

b Table VI - Lower of Table V and Freshwater Surface Water Criteria.

c Table VII - Surface Water Criteria for Resource Protection/Recovery.

d Table VIII - Low Yield/Poor Quality.

Contact: Thomas Conrardy, Florida Department of Environmental Protection 904-488-3935

Summary of Georgia Cleanup Standards for Hydrocarbon Contaminated Soil*

Product	Parameters	Lab Test Protocol & Number	Detection Level
Gasoline[1], Aviation Gas	BTEX	EPA Method 8021/8260 and	5.0 µg/kg
	PAHs	8270/8310/8100[3] and	660 µg/kg
	TPH[2]	8015 (GRO)	10 mg/kg
Diesel and Kerosene, Jet Fuel A, #2 and #4 Fuel Oil	BTEX	8021/8260 and	5.0 µg/kg
	PAHs	8270/8310/8100[3] and	660 µg/kg
	TPH[2]	8015 (DRO)	10 mg/kg
Hydraulic Oil[4], #5 and #6 Fuel Oil, Motor Oil, Used Oil	BTEX	8021/8260 and	5.0 µg/kg
	PAHs	8270/8310/8100[3] and	660 µg/kg
	TPH[2]	418.1	10 mg/kg
Mineral spirits, Jet Fuel B, or unknown petroleum contents	BTEX	8021/8260 and	5.0 µg/kg
	PAHs	8270/8310/8100[3] and	660 µg/kg
	TPH[2]	8015 (GRO and DRO)	10 mg/kg

Cleanup Constituent	Level
Volatile Organic Compounds	
Benzene	0.005 mg/kg
Toluene	0.400 mg/kg
Ethylbenzene	0.370 mg/kg
Xylenes (total)	20.00 mg/kg
Polynuclear Aromatic Hydrocarbons	
Acenaphthene	N/A[7]
Anthracene	N/A[7]
Benzo(a)anthracene	N/A[7]
Benzo(a)pyrene	0.660 mg/kg[5]
Benzo(b)fluoranthene	0.820 mg/kg[5,6]
Benzo(g,h,i)perylene	N/A[7]
Benzo(k)fluoranthene	1.60 mg/kg [5,6]
Chrysene	0.660 mg/kg[5]
Dibenz(a,h)anthracene	1.50 mg/kg [5,6]
Fluoranthene	N/A[7]
Fluorene	N/A[7]
Indeno(1,2,3-c,d)pyrene	0.660 mg/kg[5]
Naphthalene	N/A[7]
Phenanthrene	N/A[7]
Pyrene	N/A[7]

Note: Soil cleanup levels shown here are for average or higher groundwater pollution susceptibility area (where public water supplies exist within 2.0 miles and/or non-public supplies exist within 0.5 miles). These levels also reflect a distance of less than or equal to 500 feet to withdrawal point. For information on cleanup levels in lower susceptibility areas and/or different distances from water sources or withdrawal points, call the department. Soil Alternate Threshold Levels (ATL) can be calculated based on site-specific data but still using applicable water standard (either MCL or Georgia In-Stream Water Quality Standard.). Soil Alternate Concentration Limits (ACL) can be calculated based on site-specific data and ACL calculated for groundwater cleanup.

Notification levels are any amount.

[1]BTEX analysis is always required, but PAHs are not required if the owner/operator, or agent thereof, can certify that only gasoline has been stored on site. [2]For information on when to analyze soil for TPH, call for information on Section II.D.3. (a)(iii). [3]Be aware that if PAHs are detected using Method 8100, you must use Method 8270 or 8310 to determine the concentrations of the individual PAHs. [4]In some cases, hydraulic oil is exempt from UST regulations. Refer to GUST Rules for details (391-3-15-.02(2)(1)). [5]Estimated Quantitation Limit. The health-based threshold level is less than the laboratory method limit of detection. [6]In order to protect surface waters, stricter soil threshold levels may apply (call for information). [7]Not applicable. The health-based threshold level exceeds the expected soil concentration under free product condition.

Contact: Shaheer Muhanna, Technical Assistance Officer, Georgia Department of Natural Resources
404-263-2687

Summary of Hawaii Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Notification Level	Action Level (Drinking Water Resource Threatened / Drinking Water Resource Not Threatened)	Cleanup Criteria
Gasoline	TPH as Gasoline	EPA Method 5030, 8015, LUFT	****	2000 / 2000 mg/kg	
	TPH Residual Fuels	EPA Method 5030, 8015, LUFT	****	5000 / 5000 mg/kg	Site Specific
	TPH Residual Distillates	EPA Method 5030, 8015, LUFT	****	5000 / 5000 mg/kg	Site Specific
	Xylene	*	****	23 / 23 mg/kg	Site Specific
	Benzene	*	****	0.05 / 1.7 mg/kg	Site Specific
	Ethylbenzene	*	****	.50 / .50 mg/kg	Site Specific
	Toluene	*	****	16 / 34 ppm	Site Specific
	Benzene	*	****	0.05 / 1.7 mg/kg	Site Specific
	Ethylbenzene	*	****	.50 / .50 ppm	Site Specific
	Toluene	*	****	16 / 34 mg/kg	Site Specific
	Naphthalene	***	****	41 / 41 mg/kg	Site Specific

* 5030/ 8015 or 5030/ 8020 or 5030/ 8240. ** 3550/ 8015 or 3540/ 8270 or 3550/ 8270 or LUFT Method. *** 3540/ 8310 or 3550/ 8310 or 3540/ 8270 or 3550/ 8270. **** All spills over 25 gallons that cannot be contained and cleaned up within 24 hours. ***** No Cleanup criteria based on TPH–however that does not preclude use as screening method.

Notes: 1. Groundwater action levels meet state surface water standards as a minimum and drinking water standards where applicable. 2. Constituent-specific soil action levels based on RBCA groundwater-protection and direct-exposure models. 3. Hawaii RBCA program can be used to develop more site-specific action levels for Soil.

Contact: Eric Sadoyama, Hawaii Department of Health, Solid and Hazardous Waste Branch
808-586-4226
esadoyama@eha.health.state.hi.us

Summary of Idaho Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8020, 8240, 8015, 8021	*	any amount	Site Specific	Site Specific
	Toluene	EPA Method 8020, 8240, 8015, 8021	*	any amount	Site Specific	Site Specific
	Ethylbenzene	EPA Method 8020, 8240, 8015, 8021	*	any amount	Site Specific	Site Specific
	Xylenes	EPA Method 8020, 8240, 8015, 8021	*	any amount	Site Specific	Site Specific
	Naphthalene	EPA Method 8020, 8240, 8015, 8021	*	any amount	Site Specific	Site Specific
	MTBE	EPA Method 8020, 8240, 8015, 8021	*	any amount	Site Specific	Site Specific
Diesel	BTEX	EPA Method 8020, 8240, 8015, 8021	*	any amount	Same as Gas	Same as Gas
	PAH	EPA Method 8100, 8270, 525.5	*	any amount	Site Specific	Site Specific

* Dependent on sample matrix and concentration, 10 mg/kg target.
Note: Idaho has developed a RBCA program for assessment and cleanup of petroleum contamination. Cleanup levels are site specific.

Contact: Bruce Wicherski, Idaho Division of Environmental Quality 208-373-0260

Summary of Illinois Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	*	**	Any amount	.03 mg/kg	Site Specific
	Ethylbenzene	*	**	Any amount	13.0 mg/kg	Site Specific
	Toluene	*	**	Any amount	12.0 mg/kg	Site Specific
	Xylenes (total)	*	**	Any amount	18.00 mg/kg	Site Specific
Other petroleum	Naphthalene	*	**	Any amount	84 mg/kg	Site Specific
	Acenaphthene	*	**	Any amount	570 mg/kg	Site Specific
	Anthracene	*	**	Any amount	7.0 mg/kg	Site Specific
	Fluoranthene	*	**	Any amount	12,000 mg/kg	Site Specific
	Fluorene	*	**	Any amount	560 mg/kg	Site Specific
	Pyrene	*	**	Any amount	2,300 mg/kg	Site Specific
	Acenaphthylene	*	.660 mg/kg	Any amount	***	Site Specific
	Benzo(g,h,i) perylene	*	.051 mg/kg	Any amount	***	Site Specific
	Phenanthrene	*	.660 mg/kg	Any amount	***	Site Specific
	Benzo(a)anthracene	*	**	Any amount	.9 mg/kg	Site Specific
	Benzo(a)pyrene	*	**	Any amount	.09 mg/kg	Site Specific
	Benzo(b) fluoranthene	*	**	Any amount	.9 mg/kg	Site Specific
	Benzo(k) fluoranthene	*	**	Any amount	9.0 mg/kg	Site Specific
	Chrysene	*	**	Any amount	88 mg/kg	Site Specific
	Dibenzo(a,H) anthracene	*	**	Any amount	.09 mg/kg	Site Specific
	Ideno(1,2,3-cd) pyrene	*	**	Any amount	.9 mg/kg	Site Specific

*Any approved USEPA SW-846 method ** Detection level is test specific unless ADL is given.
*** Any amount above ADL **Note:** The Agency has adopted Risk-Based Corrective Action (RBCA) Regulations to determine cleanup objectives if action levels are exceeded.
35 Illinois Administrative Code Part 742, Tiered Approach to Corrective Action Objectives (TACO) gives the owner/operator the option to decide if the Tier 1 levels are the action levels or they may choose to calculate a Tier 2 or 3 cleanup objective and remediate to these levels if required.

Contact: Eric Portz, Illinois Environmental Protection Agency 217-782-4869

Summary of Indiana Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Acceptable Methods	Detection Level	Notification Level	Action Level	Cleanup Level
Kerosene, Gasoline	Total Petroleum Hydrocarbons (TPH)	GC/FID 8015 – Modified (California) or GC/MS 8240/60	20ppm	any amount	On-site ≥ 100 Off-site any amount	On-site ≤ 100 Off-site 20
Naptha, Diesel	TPH	GC/FID 8015 – Modified (California) or GC/MS 8270	20ppm	any amount	On-site ≥ 100 Off-site any amount	On-site ≤ 100 Off-site 20
Waste Oil	VOC* and	GC/PID 8020 or GC/MS 8240/60	20ppm	any amount	Site Specific	Site Specific
	SVOC and	GC/MS 8270	20ppm	any amount	Site Specific	Site Specific
	TPH and	418.1 IR	20ppm	any amount	Site Specific	onsite ≤100 offsite 20
	PCB and	GC/ECD 8080/8081	1ppm	any amount	Site Specific	Site Specific
	Metals**	use the appropriate SW–846 method	set by the appropriate method	any amount	Site Specific	Site Specific

* This analysis also should include Methyl-tertiary-butyl-ether (MTBE). ** Metal scans must include: Barium, Cadmium, Chromium (total), Lead, Mercury, Nickel, and Zinc. **Note:** If TPH >1000 ppb, then run other listed parameters.

Contact: Michael Anderson, Indiana Department of Environmental Management 317-308-3092

Iowa has adopted the ASTM RBCA method for addressing Petroleum Contaminated sites. See Action levels, Tier 1 table below. The action levels are used to determine when a Tier 1 investigation is required.

567--135.14(455B) Action levels. The following corrective action levels apply to petroleum regulated substances as regulated by this chapter. These action levels shall be used to determine if further corrective action under 135.6(455B) through 135.12(455B) or 135.15(455B) is required as the result of tank closure sampling under 135.15(2) or other analytical results submitted to the department. The contaminant concentrations must be determined by laboratory analyisis as stated in 135.16(455B). Final cleanup determination is not limited to these contaminants. The contamination corrective action levels are:

Iowa Action Levels for Soils and Groundwater

Product	Soils (mg/kg)	Groundwater (µg/L)
Benzene	0.54	5
Toluene	42	1000
Ethylbenzene	15	700
Xylene	No limit	10,000
Total Extractable Hydrocarbons	3,800	1.200

Contact: Jim Humeston, Iowa Department of Natural Resources 515-281-8957

Iowa Tier 1 Look-up Table

Media	Exposure Pathway	Group 1					Group 2 TEH	
		Receptor	Benzene	Toluene	Ethylbenzene	Xylenes	Diesel	Waste Oil
Soil (mg/kg)	Soil Leaching to Groundwater	all	0.54	42	15	NA	3,800	NA
	Soil Vapor to Enclosed Space	all	1.16	48	79	NA	50,500	NA
	Soil to Plastic Water Line	all	1.8	120	43	NA	10,500	NA

Note: NA= Not applicable. There are no limits for the chemical for the pathway, because for groundwater pathways the concentration for the designated risk would be greater than the solubility of the pure chemical in water, and for soil pathways the concentration for the designated risk would be greater than the soil concentration if pure chemical were present in the soil. ·

TEH: Total Extractable Hydrocarbons. The TEH value is based on risks from naphthalene, benzo(a)pyrene, benzo(a)anthracene, and chrysene.

Diesel: Standards in the the diesel column apply to all low volatile petroleum hydrocarbons except waste oil.

Contact: Jim Humeston, Iowa Department of Natural Resources 515-281-8957

Summary of Kansas Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Action Level	Cleanup Level
Gasoline	TPH	*	10ppm	100 ppm	100ppm
	Benzene	EPA Method 8015	.14ppm	1.4 ppm	1.4ppm
	1, 2 Dichloroethane	EPA Method 8015	.8ppm	8 ppm	8ppm
Diesel	TPH	*	10ppm	100 ppm	100ppm
Waste Oil	TPH	*	10ppm	100 ppm	100ppm

*Purge and trap, Summation of peaks chromatograph. IR method (418.1) is allowable for TPH analysis in soil for waste oil only

Note: Kansas expects to implement a Risk-Based Corrective Action (RBCA) approach in 1998, but these standards will remain in place as baseline standards.

Contact: Thomas Winn, Kansas Department of Health & Environment 913-296-1684

Summary of Kentucky Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline*	Benzene	EPA Method 8240, 8260, 8020 or 8021	0.01ppm	0.01ppm	0.01ppm	0.01 to 20ppm
	Toluene	EPA Method 8240, 8260, 8020 or 8021	0.7ppm	0.7ppm	0.7ppm	0.7 to 180ppm
	Xylene	EPA Method 8240, 8260, 8020 or 8021	5.0ppm	5.0ppm	5.0ppm	5.0 to 500ppm
	Ethylbenzene	EPA Method 8240, 8260, 8020 or 8021	0.9ppm	0.9ppm	0.9ppm	0.9 to 300ppm
Diesel	Chrysene	EPA Method 8100, 8270 or 8310	15,000ppb	15,000ppb	15,000ppb	15,000ppb
	Benzo(a)anthracene	EPA Method 8100, 8270 or 8310	150ppb	150ppb	150ppb	150ppb
	cPAH	EPA Method 8100, 8270 or 8310	300ppb	300ppb	300ppb	300ppb
	nPAH	EPA Method 8100, 8270 or 8310	3,000ppb	3,000ppb	3,000ppb	3,000 to 10,000ppb
	Naphthalene	EPA Method 8100, 8270 or 8310	1,000ppb	1,000ppb	1,000ppb	1,000 to 50,000ppb
Waste Oil	Chrysene	EPA Method 8100, 8270 or 8310	15,000ppb	15,000ppb	15,000ppb	15,000ppb
	Benzo(a)anthracene	EPA Method 8100, 8270 or 8310	150ppb	150ppb	150ppb	150ppb
	cPAH	EPA Method 8100, 8270 or 8310	300ppb	300ppb	300ppb	300ppb
	nPAH	EPA Method 8100, 8270 or 8310	3,000ppb	3,000ppb	3,000ppb	3,000 to 10,000ppb
	Naphthalene	EPA Method 8100, 8270 or 8310	1,000ppb	1,000ppb	1,000ppb	1,000 to 50,000ppb
	Total Lead	EPA Method 7420, 7421 or 6010	50ppm or established background	over background or >50ppm	over background or >50ppm	less than background or < 50ppm

*These values vary depending on facility classification, see 080E.

Contact: Doyle Mills, Division of Waste Management 502-564-6716

Louisiana Cleanup Standards

Louisiana Standards are handled on a site by site basis. Standards vary according to site conditions and program requirements. Call applicable division for standards.

UST	(504) 765-0243
General Inquiries	(504) 765-0585
Solid Waste	(504) 765-0249
Haz Waste	(504) 765-0355
CERCLA	(504) 765-0487

Summary of Maine Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Total Gasoline	Gas Range Organics (4.2.17)	1ppm	100ppm by Field/Headspace*		5mg/kg**
Diesel	Total Fuel Oil	Diesel Range Organics (4.1.25)	5ppm	100ppm by Field/Headspace*		10mg/kg***

Same note as above
* using PID or FID calibrated to DEP-established calibration set points. (A list of approved instruments and their set points is available from DEP.)
** ST and IN sites only; BL-2 sites may be cleaned to 500-1000 ppm, measured by field/headspace
*** ST and IN sites only; BL-2 sites may be cleaned to 200-400 ppm, measured by field/headspace

Contact: Fred Lavallee, Maine Department of Environmental Protection 207-287-2651

Summary of Maryland Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Notification Level (1)	Action Level	Cleanup Level (2)
Gasoline	BTEX, MTBE	EPA Method 602, 8020, 8240, 8260*	Any amount	> Background	Site Specific or 10 ppm
	TPH	EPA Method 8015M GRO	Any amount	> Background	Site Specific or 10 ppm
Diesel Fuel/ #2 Heating Oil	TPH	EPA Method 8015M DRO	Any amount	> Background	Site Specific or 10 ppm
	BTEX, Naphthalene	EPA Method 8020	Any amount	> Background	Site Specific or 10 ppm
Heavy Oil #4, 5, 6, Bunker C	TPH	EPA Method 418.1M**	Any amount	> Background	Site Specific or 10 ppm
	PAH	EPA Method 8270	Any amount	> Background	Site Specific or 10 ppm
Used Oil	TPH	EPA Method 418.1M**	Any amount	> Background	Site Specific or 10 ppm
	Full Volatile	EPA Method 8260	Any amount	> Background	Site Specific or 10 ppm
	TCLP Metals	EPA Method 6010	Any amount	> Background	Site Specific or 10 ppm
	PAH	EPA Method 8270	Any amount	> Background	Site Specific or 10 ppm

Note: There are no promulgated cleanup standards. All decisions on "how clean is clean" are made via site-specific risk characterization. For groundwater there are no promulgated cleanup standards.

If more than one of the suspected products listed above may be present in an excavation area, then analyses for all applicable constituents should be used to assess the soil. Test methods may be altered on a site-specific basis by an MDE representative. Sampling of a listed hazardous material storage system will be agreed upon on a site-specific basis. Soil treatment facilities and disposal sites may require further or different analyses.

*Full volatile 8260 may be required in domestic well areas. ** Being replaced by Method 1664.

Contact: Herb Meade, Maryland Department of the Environment 410-631-3442

Summary of Massachusetts Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Notification Level (1)	Cleanup Level (2) A / B / C
Gasoline	Benzene	NS	10/60 µg/g	10-200 µg/g or site specific
	Toluene	NS	90/500 µg/g	90-2500 µg/g or site specific
	Ethylbenzene	NS	80/500 µg/g	80-2500 µg/g or site specific
	Total Xylenes	NS	500/500 µg/g	500-2500 or site specific
	MtBE	NS	0.3/200 µg/g	0.3-200 µg/g or site specific
	Naphthalene	NS	4/1000 µg/g	4-1000 µg/g or site specific
	C5-C8 Aliphatic Hydrocarbons	MADEP VPH	100/500 µg/g	100-500 µg/g or site specific
	C9-C12 Aliphatic Hydrocarbons	MADEP VPH	1000/2500 µg/g	1000-5000 µg/g or site-specific
	C9-C10 Aromatic Hydrocarbons	MADEP VPH	100/500 µg/g	100-500 µg/g or site specific
Diesel/	Naphthalene	NS	4/1000 µg/g	4-1000 µg/g or site specific
#2 Fuel	2-Methylnapthalene	NS	4/1000 µg/g	4-1000 µg/g or site specific
	Phenanthrene	NS	100/100 µg/g	100 µg/g or site specific
	Acenaphthene	NS	20/2500 µg/g	20-4000 µg/g or site specific
	C9-C18 Aliphatic Hydrocarbons	MADEP EPH	1000/2500 µg/g	1000-5000 µg/g or site specific
	C19-C36 Aliphatic Hydrocarbons	MADEP EPH	2500/5000 µg/g	2500-5000 µg/g or site specific
	C11-C22 Aromatic Hydrocarbons	MADEP EPH	200/2000 µg/g	100-500 µg/g or site specific

Note: µg/g = ppm mass/mass dry weight basis. NS=Not Specified in regulation. (1) Two notification thresholds have been established for "high" and "low" exposure potential areas. (2) Nine generic cleanup standards have been established depending upon exposure potential/accessibility of soil, and use/classification of underlying groundwater. Alternative cleanup levels are permissible based upon a site-specific risk characterization. See Massachusetts regulations 310 CMR 40.000 and associated support/policy documents for complete details and requirements - MADEP on the World Wide Web - http://www.magnet.state.ma.us/dep

Contact: John J. Fitzgerald, Massachusetts Dept. of Environmental Protection
617-932-7702
e-mail: john.fitzgerald@state.ma.us

Summary of Michigan Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Criteria Residential
Gasoline	Benzene	8020, 8021, 8240A, 8260A, CLP-SOW	10ppb	any amount	same as cleanup criteria	100ppb
	Toluene	8020, 8021, 8240A, 8260A, CLP-SOW	10ppb	any amount	same as cleanup criteria	16,000ppb
	Ethylbenzene	8020, 8021, 8240A, 8260A, CLP-SOW	10ppb	any amount	same as cleanup criteria	1500ppb
	Xylenes	8020, 8021, 8240A, 8260A, CLP-SOW	30ppb	any amount	same as cleanup criteria	5600ppb
Premium Gas	MTBE	8021, 8240A, 8260A	100ppb	any amount	same as cleanup criteria	4800ppb
Leaded Gas	Lead	6 listed methods	1000ppb			
	PNAs	EPA Method 1625C, 8270A, 8310, CLP-SOW	330ppb	any amount	same as cleanup criteria	Varies By Component

Note: Other metals and organic solvents of waste oils need to be tested for. Call MDNR for information. Alternative cleanup criteria may be available under certain curcumstances.

Contact: Christine Flaga, Michigan Department of Natural Resources, Environmental Response Division 517-373-0160

Summary of Minnesota Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	Wisconsin DNR GRO Method	any amount	40 ppm**	Site Specific****
	BTEX	*	any amount	40 ppm**	Site Specific****
	MTBE	*	any amount	40 ppm**	Site Specific****
Diesel	TPH	Wisconsin DNR DRO Method	any amount	10 ppm***	Site Specific****
	BTEX	*	any amount	10 ppm***	Site Specific****
Waste Oil	Same as Diesel →				

* All samples, unless specifically noted, should use an EPA approved method or equivalent. ** Soil Vapor headspace analysis ≥ 40ppm. *** Visual evidence of contamination or soil vapor headspace ≥ 10 ppm.
**** Additional investigation needed if base, sidewall soil samples are >50ppm TPH for sands.

Contact: Steve Thompson, Minnesota Pollution Control Agency, Tanks & Emergency Response 612-297-8603

Summary of Mississippi Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	BTEX	EPA Method 602, 624, 8020, 8240, 8260	*	any amount	100 ppm or over	**
Diesel	TPH	EPA Method 418.1	4ppm	any amount	100 ppm or over	**
Waste Oil	TPH	EPA Method 418.1	1ppm	any amount	100 ppm or over	**

* Benzene-11.25ppb, Toluene-12.5ppb, Ethylbenzene-6.25ppb, Meta & Para Xylene-12.5ppb.
** 100ppm or less if no sensitive environmental receptors present.

Contact: Martha Martin, Mississippi Underground Storage Tank Division 601-961-5058

Summary of Missouri Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	EPA Method 418.1 Modified	5.0ppm	25ppm	Site Specific	Site Specific/50-500ppm
	Benzene	EPA Method 8020 or 8240	.05ppm	.5ppm	Site Specific	Site Specific Min (Total BTEX<2ppm)
	Toluene	EPA Method 8020 or 8240	.05ppm	Total BTEX 1ppm	Site Specific	Max (Benzene 2ppm, Toluene 10ppm,
	Ethylbenzene	EPA Method 8020 or 8240	.05ppm	Total BTEX 1ppm	Site Specific	Ethylbenzene 50ppm, Xylene 50ppm)
	Xylene	EPA Method 8020 or 8240	.05ppm	Total BTEX 1ppm	Site Specific	
Diesel	Same as Gasoline →					
	BTEX	EPA Method 8240	Same as Gasoline →			
	Heavy Metals	EPA Method 1311/6010 (TCLP)	40 mg/kg	Contact the Environmental Services Program, Site Specific		

Note: In January 1998 new regulations are expected to be implemented, with changes in reporting levels, cleanup levels and lab analysis. Contact Department of Natural Resources for information on new guidelines. **Note:** TCLP Regulatory levels in 40CFR 261.24.

Contact: Shirley Abshier, Missouri Department of Natural Resourses 816-554-4100

Summary of Montana Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	GRO**	100 ppm	>100ppm	Site Specific ≥100ppm
	Benzene	EPA Method 8020, 8260	1 ppm	>1ppm	Site Specific ≥1ppm
	Total BTEX	EPA Method 8020, 8260	10 ppm	>10ppm	Site Specific ≥10ppm
Diesel	TPH	DRO**	100 ppm	>100ppm	Site Specific ≥100ppm
Waste Oil	TPH	DRO** with a used oil standard	100 ppm	>100ppm	Site Specific ≥100ppm
	VOCs	EPA Method 8260		Site Specific	See above for BTEX*
	Cadmium, Chromium, Lead	Not Specified		Site Specific	*

* Contamination from metals and halogenated VOCs is under the jurisdiction of another program.
** Must be performed according to MDEQ guidelines.

Contact: Scott Gestring, Montana Department of Environmental Quality 406-444-1420

Summary of Nebraska Recommended Cleanup Goals for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8021, 8020 8240, 8260	≤ Cleanup Level	any amount		Site Specific
	Total BTEX	EPA Method 8021, 8020 8240, 8260	≤ Cleanup Level	any amount		Site Specific
	TRPH	EPA Method 418.1, OA2	≤ Cleanup Level	any amount		Site Specific
Diesel	Benzene	EPA Method 8021, 8020 8240, 8260	≤ Cleanup Level	any amount		Site Specific
	Total BTEX	EPA Method 8021, 8020 8240, 8260	≤ Cleanup Level	any amount		Site Specific
	TRPH	EPA Method 418.1, OA2	≤ Cleanup Level	any amount		Site Specific
Waste Oil*	TRPH	EPA Method 418.1, OA2	≤ Cleanup Level	any amount		Site Specific
	VOCs, SVOCs	EPA Method 8240/ 8260; 8270	≤ Cleanup Level	any amount		Established Case-By-Case

Note: Soil cleanup levels are based on site specific contaminants and exposure parameters.

Contact: Nancy Mann, Nebraska Department of Environmental Quality 402-471-4230

Summary of Nevada Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	EPA Method 8015 Modified	10 mg/kg	> 25 Gallons or 3 Cubic Yards	100 ppm	100 ppm
Diesel	TPH	EPA Method 8015 Modified	10 mg/kg	> 25 Gallons or 3 Cubic Yards	100 ppm	100 ppm
Waste Oil	TPH	EPA Method 8015 Modified, TCLP Inorganics	10 mg/kg	> 25 Gallons or 3 Cubic Yards	100 ppm	100 ppm

Contact: Jennifer Carr, Nevada Department of Conservation and Natural Resources 702-687-4670

Summary of New Hampshire Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level (ppm)	Cleanup Standard (ppm)
Gasoline	VOC and TPH (TPH as gasoline)	*	Test Specific	Same As Cleanup Level	Benzene>.3	.3
					1-2-Dichlorocthane>.09	.09
					Ethylbenzene >90	90
					Isopropylbenzene>23	23
					MTBE>3	3
					Toluene>100	100
					Xylenes>810	810
					TPH>10,000	10,000
No's 2,4,5,6 Fuel Oil and Diesel	VOC, PAH and TPH (TPH as oil)	**	Test Specific	Same As Cleanup Level	VOCs and TPH Same As Above	
					Napthalene >3	3
					Acenapthene >1,000	1,000
					Benzo(a,h)pyrene >.7	.7
					Benzo(b)fluoranthene >7	7
					Benzo(k)fluoranthene >7	7
					Chrysene >70	70
					Dibenzo(a)anthracene >.7	.7
					Fluoranthene >810	810
					Indeno(1.2.3-cd)pyrene >.7	.7
					2-methylnaphthalene >150	150
	Total Non-Carcinogenic PAHs				>610ppm	>610ppm

* Initially 8260 plus MTBE and P&T-GC/FID for TPH. All other samples 8020 plus MTBE or 8240 plus MTBE and P&T GCIFID for TPH.
**Initially 8260, 8270/8310 and extraction GC/FID for TPH. All other samples 8020, 8240, 8260 or 8270/8310 and extraction GC/FID for PAH.

Contact: Frederick McGarry, P.E., New Hampshire Department of Environmental Services 603-271-4978

Summary of New Jersey Cleanup Criteria for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Cleanup Criteria* Residential / Non-Resid. / Impacted Groundwater
Gasoline	Benzene	EPA Method SW 846	Test Specific	any amount	3mg/kg / 13mg/kg / 1mg/kg
	Toluene	EPA Method SW 846	Test Specific	any amount	1000mg/kg / 1000mg/kg / 500mg/kg
	Ethylbenzene	EPA Method SW 846	Test Specific	any amount	1000mg/kg /1000mg/kg / 100mg/kg
	Xylene	EPA Method SW 846	Test Specific	any amount	<410mg/kg / 1000mg/kg / 10mg/kg
	Anthracene	EPA MethodSW 846	Test Specific	any amount	10,000mg/kg / 10,000mg/kg / 100mg/kg
	Naphthalene	EPA Method SW 846	Test Specific	any amount	230mg/kg / 4200mg/kg / 100mg/kg
	Lead	EPA Method SW 846	Test Specific	any amount	400mg/kg /600mg/kg / NS
	Benzo (a) Pyrene	EPA Method SW 846	Test Specific	any amount	.66mg/kg /.66mg/kg / 100mg/kg
Diesel	Same As Above For Gasoline				

*Total Organic Compounds, CAP of 10,000mg/kg

Contact: Paul Kurisko, NJ Dept. of Environmental Protection, Site Remediation 609-633-7413

Summary of New Mexico Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level (ppm)	Action Level	Cleanup Level
	BTEX	EPA Method 8020	0.50ppm	*	*
Diesel	TPH	EPA Method 8015 Modified	25.0ppm	100 ppm	100ppm
		EPA Method 418.1		100ppm	100ppm
Waste Oil	TPH	Modified 8015		100ppm	100ppm
	Same as Diesel +		25.0ppb	Per RCRA	Per RCRA
	Semi-volatiles, Volatiles, PCBs, Metals	TLCP		Per RCRA	Per RCRA

* Total 50ppm and Benzene 10ppm

Contact: Steve Huddleson, New Mexico Environment Department 505-827-0173

Summary of New York Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action* Level	Cleanup Level
Gasoline	Benzene	EPA Method 8021 or 8020	2ppb	any amount	14ppb	Site Specific
	Ethylbenzene	EPA Method 8021 or 8020	2ppb	any amount	100ppb	Site Specific
	Toluene	EPA Method 8021 or 8020	2ppb	any amount	100ppb	Site Specific
	Xylene	EPA Method 8021 or 8020	2ppb	any amount	100ppb	Site Specific
	MTBE	EPA Method 8021 or 8020	1ppb	any amount	1000ppb	Site Specific
	Other Compounds Listed in STARS #1	EPA Method 8021	Compound Specific	any amount	Compound Specific	Site Specific
Diesel	Naphthalene	EPA Method 8021	1ppb	any amount	200ppb	Site Specific
	Fluorene	EPA Method 8270	330ppb	any amount	1000ppb	Site Specific
	Pyrene	EPA Method 8270	330ppb	any amount	1000ppb	Site Specific
	Other Compounds Listed in STARS #1	EPA Method 8021 or 8270	Compound Specific	any amount	Compound Specific	Site Specific
Waste Oil	PCBs	EPA Method 8270	Compound Specific	Compound Specific	Compound Specific	Compound Specific
	Halogenated Organics	EPA Method 8021	Compound Specific	Compound Specific	Compound Specific	Compound Specific
	See Diesel Parameters Above →					

* These levels are based upon the highest concentration in the soil, which if analyzed by TCLP extraction method, would not yield a value in excess of the GW action level.

Contact: Chris O'Neill, New York Department of Environmental Conservation 518-457-9412

Summary of North Carolina Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level***	Action Level***	Cleanup Level
Gasoline, Aviation Fuels	TPH	5030 sample prep. with modified 8015	MDL	10 ppm	10 ppm	Site Specific*
Diesel, Kerosene	TPH	5030 sample prep. with modified 8015	MDL	10 ppm	10 ppm	Site Specific*
		3550 sample prep. with modified 8015		40 ppm	40 ppm	
Heavy Fuels (Virgin Products)	TPH	9071	MDL	> 250 ppm	> 250 ppm	Site Specific*
Waste Oil	TPH	9071[1] 8021 (8270)	MDL	> 250 ppm > MDL (>MDL)	> 250 ppm > MDL (>MDL)	Site Specific*
Metals	Pb, Ba, As, Cd, Cr, Ag, Hg, Se	1311 (TCLP)	MDL	> Cleanup level **	> Cleanup Level	Naturally Occurring Background Concentrations

Note: MDL = Method Detection Limit. Laboratories must be certified by NC DWQ to perform all methods used.

Contact: Betty Wilcox, North Carolina Division of Water Quality 919-715-6167

*North Carolina uses a Site Sensitivity evaluation and risk-based levels to determine cleanup levels.
** Notify DWM-Hazardous Waste (919-733-2178) if TCLP limits are exceeded.
*** North Carolina is phasing out TPH-based action levels and adopting risk-based, compound-specific action and cleanup levels.

[1] If 9071 > 250 ppm, run 8270 with PCBs

Summary of North Dakota Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	TPH	Modified EPA 8015		any amount	100 ppm	Site Specific
Diesel	TPH	Modified EPA 8015		any amount	100 ppm	Site Specific
Waste Oil	BTEX	EPA Method 8020		any amount	.5mg/l Benzene	
	Lead	EPA Method 239.2		any amount	5mg/l	
	TOX	EPA Method 9020, 9022		any amount	1000mg/l	

Contact: Dave Glatt, North Dakota State Department of Health 701-328-5217

Summary of Ohio Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8020	Method Specific	Action Level Based	0.006–0.500ppm	Site Specific
	Toluene	EPA Method 8020	Method Specific	Action Level Based	4–12ppm	Site Specific
	Ethylbenzene	EPA Method 8020	Method Specific	Action Level Based	6–18ppm	Site Specific
	Total Xylenes	EPA Method 8020	Method Specific	Action Level Based	28–85ppm	Site Specific
	TPH	Modified Method 8015	Method Specific	Action Level Based	105–600 ppm	Site Specific
Diesel	Benzene	EPA Method 8020	Method Specific	Action Level Based	0.006 –0.500	Site Specific
	Toluene	EPA Method 8020	Method Specific	Action Level Based	4–12ppm	Site Specific
	Ethylbenzene	EPA Method 8020	Method Specific	Action Level Based	6–18 ppm	Site Specific
	Total Xylenes	EPA Method 8020	Method Specific	Action Level Based	28–85ppm	Site Specific
	PNAs	EPA Method 8100	Method Specific	Any Level	Site Specific	Site Specific
	TPH	EPA Method 418.1	Method Specific	Any Level	380–1156ppm	Site Specific
Waste Oil	Volatile Organic Aromatics	EPA Method 8240	Method Specific	Any Level	Site Specific	Site Specific
	TPH	EPA Method 418.1	Method Specific	Action Level Based	380–1156ppm	Site Specific

Note: The State of Ohio is currently drafting rules that will detail how Risk Based Corrective Action (RBCA) is to be utilized in Ohio. Projected date of revised corrective action rule is April 1, 1998.

Contact: Raymond Roe, Ohio Department of Commerce 614-752-7938

Summary of Oklahoma Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number*	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline, Diesel and Kerosene	TPH	EPA Method 8015	1ppm	any amount above action level	TPH>50ppm B>.5ppm	Site Specific RBCA Standards Site Specific RBCA Standards
	BTEX	EPA Method 8020	1ppm	any amount above action level	T>40ppm E>15ppm X>200ppm	Site Specific RBCA Standards Site Specific RBCA Standards Site Specific RBCA Standards

Note: Oklahoma uses a Remediation Index in determining cleanup standards on a site-by-site basis.
* Whatever method is specified must be able to detect the most stringent cleanup levels. EPA Method 418.1 is not accepted testing method for TPH.

Contact: Dick Oppel, Oklahoma Corporation Commission, Underground Storage Tank Program 405-522-5264

Summary of Oregon Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Cleanup Level
Gasoline	TPH	DEQ Method, TPH-G	10 mg/kg	any amount	Site Specific, Level 1=40ppm, Level 2=80ppm Level 3=130ppm
Diesel	TPH	DEQ Method, TPH-D or TPH-418.1	20 mg/kg	any amount	Site Specific Level 1=100ppm, Level 2=500ppm, Level 3=1000ppm,
Waste Oil	TPH	DEQ Method,TPH-418.1		any amount	(Same as Diesel)

Note: Oregon uses a site scoring matrix to determine TPH cleanup standards in soil. Oregon released interim guidance in April 1996 on the application of risk-based corrective action (RBCA) at petroleum cleanup sites. The implementation of risk-based decisions may affect how the cleanup levels in these tables are applied. Rule changes incorporating RBCA will be initiated in fall of 1997.

Contact: Michael Anderson, Oregon Department of Environmental Quality 503-229-6764

Summary of Rhode Island Standards for Hydrocarbon Contaminated Soil[a]
Direct Exposure Criteria (Residential and Industrial/Commercial)

Product	Parameter Constituent	Lab Test[b] Protocol & Number	Cleanup Level[f] Residential	Cleanup Level[f] Ind./Commercial
Gasoline	TPH	EPA Method 8015 Modified[c]	500 or 1000 ppm[e]	2500 ppm
	Benzene	EPA Method 8020, 8240 or 8260	2.5 ppm	200 ppm
	Toluene	EPA Method 8020, 8240 or 8260	190 ppm	10,000 ppm
	Ethylbenzene	EPA Method 8020, 8240 or 8260	71 ppm	10,000 ppm
	Xylenes (Total)	EPA Method 8020, 8240 or 8260	110 ppm	10,000 ppm
	MTBE	EPA Method 8020	390 ppm	10,000 ppm
	Naphthalene	EPA Method 8020 or 8260	54 ppm	10,000 ppm
Diesel	TPH	EPA Method 8015 Modified[c] or Method 8100 Modified[d]	500 or 1000 ppm[e]	2500 ppm
	BTEX, MTBE and Naphthalene	Same as gasoline	Same as gasoline	Same as gasoline
Waste Oil	TPH	EPA Method 8100 Modified[d]	500 or 1000 ppm[e]	Same as gasoline
	BTEX, MTBE and Naphthalene	Same as gasoline	Same as gasoline	Same as gasoline

a These Direct Exposure Criteria for contaminated soils are only applicable to sites managed under the RIDEM Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases (Remediation Regulations), as amended August 1996. Sites with hydrocarbon contaminated soil resulting exclusively from a Leaking Underground Storage Tank (LUST) are managed by the RIDEM LUST Program on a site by site basis.
b Preferred lab analytical test methods are recommended in the Remediation Regulations, but not specifically required.
c TPH by EPA Method 8015 modified (purge and trap) - GC/FID.
d TPH by EPA Method 8100 modified (extraction) - GC/FID.
e The Residential TPH Direct Exposure Criterion may be 1000 ppm contingent upon field-verification by Department personnel to ensure that short-term risks are managed appropriately prior to approval as a final remedial objective.
f The reportable concentrations for soil are the same as the cleanup levels.

Contact: Greg Fine, Rhode Island Department of Environmental Management, 401-277-3872

Summary of Rhode Island Standards for Hydrocarbon Contaminated Soil[a]
Leachability Criteria (GA and GB)[b]

Product	Parameter/ Constituent	Lab Test[c] Protocol & Number	Cleanup Level[g] GA Leachability	Cleanup Level[g] GB Leachability
Gasoline	TPH	EPA Method 8015 Modified[d]	500 or 1000 ppm[f]	2500 ppm
	Benzene	EPA Method 8020, 8240 or 8260	0.2 ppm	4.3 ppm
	Toluene	EPA Method 8020, 8240 or 8260	32 ppm	54 ppm
	Ethylbenzene	EPA Method 8020, 8240 or 8260	27 ppm	62 ppm
	Xylenes (Total)	EPA Method 8020, 8240 or 8260	540 ppm	Not specified
	MTBE	EPA Method 8020	0.9 ppm	100 ppm
	Naphthalene	EPA Method 8020 or 8260	0.8 ppm	Not specified
Diesel	TPH	EPA Method 8015 Modified[d] or Method 8100 Modified[e]	500 or 1000 ppm[f]	2500 ppm
	BTEX, MTBE and Naphthalene	Same as gasoline	Same as gasoline	Same as gasoline
Waste Oil	TPH	EPA Method 8100 Modified[e]	500 or 1000 ppm[f]	Same as gasoline
	BTEX, MTBE and Naphthalene	Same as gasoline	Same as gasoline	Same as gasoline

a These Leachability Criteria for contaminated soils are only applicable to sites managed under the RIDEM Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases (Remediation Regulations), as amended August 1996. Sites with hydrocarbon contaminated soil resulting exclusively from a Leaking Underground Storage Tank (LUST) are managed by the RIDEM LUST Program on a site by site basis. Although the RIDEM LUST Program uses the Leachability Criteria as goals, the standards are not enforceable by the regulations covering LUSTs.
b Groundwater classified as GA is presumed to be suitable for use as drinking water without treatment. Groundwater classified as GB is presumed to be degraded and not suitable for use as drinking water without treatment.
c Preferred lab analytical test methods are recommended in the Remediation Regulations, but not specifically required.
d TPH by EPA Method 8015 modified (purge and trap) - GC/FID.
e TPH by EPA Method 8100 modified (extraction) - GC/FID.
f The GA TPH Leachability Criterion may be 1000 ppm and may be field-verification at the discretion of the Department to ensure that short-term risks are managed appropriately prior to approval as a final remedial objective.
g The reportable concentrations for soil are the same as the soil cleanup levels.

Contact: Greg Fine, Rhode Island Department of Environmental Management, 401-277-3872

Summary of South Carolina Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gas, Diesel, Kerosene	Benzene	8260	5 ppb	any amount	5 ppb	site specific/risk
	Toluene	8260	5 ppb	any amount	730 ppb	site specific/risk
	Ethylbenzene	8260	5 ppb	any amount	1190 ppb	site specific/risk
	Xylene	8260	5 ppb	any amount	16,900 ppb	site specific/risk
	Naphthalene	8260	5 ppb	any amount	70 ppb	site specific/risk
	MTBE	8260	5 ppb	any amount	40 ppb	site specific/risk
	Benzo(a)anthracene	8270	660 ppb	any amount	660 ppb	site specific/risk
	Benzo(B)fluoranthene	8270	660 ppb	any amount	660 ppb	site specific/risk
	Benzo(k)fluoranthene	8270	660 ppb	any amount	1260 ppb	site specific/risk
	Chrysene	8270	660 ppb	any amount	660 ppb	site specific/risk
	Dibenz(a,h)anthracene	8270	660 ppb	any amount	1260 ppb	site specific/risk
Waste Oil	Same as Gasoline					
	TPH	9071	10 ppm	any amount	NA*	site specific/risk
	Metals	AA-ICP	**	anv amount	**	site specific/risk

Note: Action levels are for impacted soil located less than 5 feet from groundwater. For depths to groundwater exceeding 5 feet, action levels are higher.
*No action or cleanup levels. TPH is used solely to determine necessity of performing expanded analyses.
**Best obtainable reporting level. Necessity of action based on comparison with background.

Contact: Read Miner, South Carolina Department of Health & Environmental Control 803-734-5327

Summary of South Dakota Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA 8020, 8015 or equivalent	.2ppm	above detection levels	**	**
	Toluene	EPA 8020, 8015 or equivalent	15ppm	above detection levels	**	**
	Ethylbenzene	EPA 8020, 8015 or equivalent	10ppm	above detection levels	**	**
	Xylene	EPA 8020, 8015 or equivalent	300ppm	above detection levels	**	**
	TPH*		500ppm	above detection levels	**	**
Diesel	Naphthalene	If >25 must be confirmed by GC/MS		25ppm	**	**
	TPH*		500ppm	0.1ppm	**	**
Waste Oil	TPH* (Other constituents based on composition of waste oil)		500ppm	0.1ppm	**	**

* California/ USGS method or similar methods that can quantify TPH by integrating all detectable peaks within the time period in which 95% of the recoverable hydrocarbons are eluted.
** Cleanup is not required if risks to human health are not present. Source removal is required. If risks are present cleanup is done to site specific target levels or the Tier I action Levels(detection levels).

Contact: Doug Miller, Department of Environmental and Natural Resources 605-773-3296

Summary of Tennessee Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level[1]
Gasoline	Benzene	SW-846 5030 P&T, 8020 GC	0.002 ppm	> 5.0 ppm	> 5.0 ppm	5.0 ppm to 100 ppm
	TPH-GRO	TN TPH-GRO	5.0 ppm	> 100 ppm	> 100 ppm	100 ppm to 1000 ppm
Diesel Range	TPH-DRO	TN TPH-DRO	4.0 ppm	> 100 ppm	> 100 ppm	100 ppm to 1000 ppm
Waste Oil	TPH	418.1 or 503E	100 ppm	> 100 ppm	>100 ppm	100 ppm to 1000 ppm

[1] Cleanup levels are based on groundwater classification and soil permeability.

Contact: Curtis Hopper, Tennessee Department of Environment and Conservation 615-532-0956

Summary of Texas Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Toluene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Ethylbenzene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Xylene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	TPH	EPA Method 418.1	10mg/kg	any amount	*	None***
Diesel	Benzene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Toluene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Ethylbenzene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	Xylene	EPA Method 8020	.5mg/kg	any amount	*	Site Specific/Risk-based**
	TPH	EPA Method 418.1	10mg/kg	any amount	*	None***
	PAHs	EPA Method 8100, 8270, 8310	Chemical Specific	any amount	*	Site Specific/Risk-based**
Waste Oil	BTEX	EPA Method 8020	.5mg/kg each	any amount	*	Site Specific/Risk-based**
	TPH	EPA Method 418.1	10mg/kg	any amount	*	None***
	VOCs	EPA Method 8240	Chemical Specific	any amount	*	Site Specific/Risk-based**
	PAH	EPA Method 8100, 8270, 8310	Chemical Specific	any amount	*	Site Specific/Risk-based**

* Product Specific/ Site Specific.
** No Range Available. Based on set procedures. ***Not used for establising cleanup goals.

Contact: Chris Chandler, Texas Natural Resource Conservation Commission 512-239-2200

Utah has implemented Tier 1 RBCA - the following Cleanup levels are "screening levels" and can only be applied when the Tier 1 worksheet is complete and no receptors are within 30 feet of the source area.

Utah Action Levels for Soils

Product	Soils (mg/kg)
Benzene	.9
Toluene	61
Ethylbenzene	23
Xylenes	235
Naphthalene	10
TPH-gasoline	1500
TPH-diesel	5000
Oil & Grease/TRPH	10,000

Contact: Robin D. Jenkins, Division of Environmental Response and Remediation 801-536-4100

Summary of Vermont Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
**Gasoline	BTEX	EPA Method 8020	100ppb	any amount	*	Site Specific
**Diesel	BTEX	EPA Method 8020		any amount	*	
	TPH	EPA Method 418.1 or Extended GC	10ppm	any amount	1000 ppm	Site Specific
Waste Oil	VOCs	EPA Method 8240	100 µg/kg	any amount	*	Site Specific

* 20 times the groundwater enforcement standard for specific compounds.
**Vermont encourages the use of Photoionization Device (PID) for field screening soils during initial site assessments.

Contact: Chuck Schwer, Vermont Agency of Environmental Conservation 802-241-3876

Summary of Virginia Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Cleanup Level
Gasoline	BTEX	EPA Method 8020	*	any amount	Site Specific/Risk Based
	TPH	Cal Luft Method Wisconsin GRO	10 mg/kg	any amount	Site Specific/Risk Based
Diesel	BTEX	EPA Method 8020	*	any amount	Site Specific/Risk Based
	TPH	Cal Luft Method Wisconsin DRO	10 mg/kg	any amount	Site Specific/ Risk Based
Waste Oil	TPH	SW–846 9701 Wisconsin TRPH	*	any amount	Site Specific/Risk Based

* PQL for constituents as stated in SW846. Note: Methods above are required for remediation monitoring under permit. During Site Characterization, Closure, etc, all EPA approved methods and Cal Luft Method for TPH are acceptable.

Contact: Dave Chance, Virginia DEQ 804-698-4288

Summary of Washington Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Cleanup Level
Gasoline	Benzene	EPA Method 8020 or 8260	*	any amount	0.5mg/kg
	Ethylbenzene	EPA Method 8020 or 8260	*	any amount	20mg/kg
	Toluene	EPA Method 8020 or 8260	*	any amount	40mg/kg
	Xylenes	EPA Method 8020 or 8260	*	any amount	20mg/kg
	Total Lead	EPA Method 6010, 7420 or 7421	*	any amount	250mg/kg
Diesel	TPH	NWTPH-DX	*	any amount	200mg/kg**
Waste Oil	TCLP	EPA Method 1311	*	any amount	Analyte Specific
	PCBs	EPA Method 8080	*	any amount	1mg/kg
	Volatile Organics	EPA Method 8021 or 8260	*	any amount	Analyte Specific
	Phenols	EPA Method 8040 or 8270	*	any amount	Analyte Specific
	PAHs	EPA Method 8100 or 8270	*	any amount	1mg/kg
	Total Metals	EPA Method 6010 and 7000 series	*	any amount	Metal Specific

* Test Specific. ** Method B and C levels for TPH must be set on a site specific basis using the TPH Interim Policy. **Note:** Washington State has rating matrix for establishing cleanup standards. Cleanup levels shown are Method A numbers for routine cleanups. Method B and C also exist; Method B for "Residential" and Method C for "Industrial", which are risk-based. The Department of Ecology should be consulted on the applicability of Methods B and C. Method B levels may be lower to protect groundwater.

Contact: Steve Robb, Washington Department of Ecology 360-407-7188

Summary of West Virginia Cleanup Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8020	any amount	50ppb	Site Specific
	Toluene	EPA Method 8020	any amount	10ppm total BTEX	Site Specific
	Ethylbenzene	EPA Method 8020	any amount	10ppm total BTEX	Site Specific
	Xylenes	EPA Method 8020	any amount	10ppm total BTEX	Site Specific
	TPH	EPA Method 8015 Modified*		50ppm	Site Specific
Diesel	Benzene	EPA Method 8020	any amount	50ppb	Site Specific
	Toluene	EPA Method 8020	any amount	10ppm total BTEX	Site Specific
	Ethylbenzene	EPA Method 8020	any amount	10ppm total BTEX	Site Specific
	Xylenes	EPA Method 8020	any amount	10ppm total BTEX	Site Specific
	TPH	EPA Method 8015 Modified*		100ppm	Site Specific

* Report GRO and DRO separately

Note: Some leaking underground storage tank sites may qualify for West Virginia's voluntary cleanup program, which utilizes Risk Based Corrective Action (RBCA).

Contact: Mike Sutphin, West Virginia Department of Environmental Protection 304-558-6371

Summary of Wisconsin Criteria* for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	GRO	WI DNR Modified GRO Method	**	any amount	10µg/kg	100µg/kg or Site Specific
	PVOC[1] VOC[3]	EPA Method 8260 or 5030/8020 or 5030/8021	**	any amount	Any Amount[5]	*** or Site Specific 50µg/kg or Site Specific
	Pb, Cd	EPA Method 3050/ 7420 or 3050/7421 or 3050/6010	**	any amount	Any Amount[5]	8µg/kg or Site Specific
Diesel	DRO	WI DNR Modified DRO Method	**	any amount	10 µg/kg	100µg/kg or Site Specific
	PVOC	EPA Method 8260 or 5030/8020 or 5030/8021	**	any amount	Any Amount[5]	*** or Site Specific
	PAH[3]	EPA Method 8310HPLC 3540/8270 or 3550/8270	**	any amount	Any Amount[5]	Site Specific
Waste Oil	PAH[3]	EPA Method 8310HPLC 3540/8270 or 3550/8270	**	any amount	Any Amount[5]	Site Specific
	VOC[2, 3]	EPA Method 5030/8021 or 8260	**	any amount	Any Amount[5]	Site Specific
	PVOC	EPA Method 5030/8020 or 5030/8021 or 8260	**	any amount	Any Amount[5]	*** or Site Specific
	PCB	EPA Method 3540/8080 or 3550/ 8080	**	any amount	Any Amount[5]	Site Specific

* Wisconsin Admin. Code NR720 ** Test Specific. ***Benzene-5.5µg/kg, Toluene-1500µg/kg, Ethylbenzene-2900µg/kg, Xylenes-1100µg/kg, 1.2. dichloroethane-4.9µg/kg.

[1]Petroleum Volatile Organic Compounds-defined in Analytical Guidance. [2]Sample at least once. [3]See Analytical Guidance. [4]At tank removal. [5]Site specific-may require investigation, may require cleanup.

Contact: Carol McCurry, Wisconsin Department of Natural Resources 608-266-5425

Summary of Wyoming Clean–up Standards for Hydrocarbon Contaminated Soil

Product	Parameter/ Constituent	Lab Test Protocol & Number	Detection Level	Notification Level	Action Level	Cleanup Level
Gasoline	Benzene	EPA Method 8020	0.1mg/kg	any amount	*	*
	Ethylbenzene	EPA Method 8020	0.1mg/kg	any amount	*	*
	Toluene	EPA Method 8020	0.1mg/kg	any amount	*	*
	Xylenes	EPA Method 8020	0.1mg/kg	any amount	*	*
Leaded Gas	Total Lead	EPA Method 289.2/6010	5mg/kg	any amount	*	*
	TPH	Modified 8015 GRO	4mg/kg	any amount	>30mg/kg >100mg/kg	30mg/l gw<50' 100mg/l gw>50'
Fuel Oils	BTEX same as Gasoline					
	TPH	Modified 8015 DRO	4 mg/kg	any amount	>100mg/kg	100mg/kg
Lubricating Oil	BTEX and TPH same as Fuel Oil					
Waste Oil	BTEX same as Gasoline					
	TPH	Extraction Method (GC)	5 mg/kg	any amount	>100mg/kg	100mg/kg
	Total Lead	EPA Method 239.9/ 6010	5 mg/kg	any amount	*	*
	Total Cadmium	EPA Method 213.1/ 6010	.5 mg/kg	any amount	*	*
	Total Chromium	EPA Method 218.1/ 6010	.5 mg/kg	any amount	*	*

* Site Specific. **Note:** Site Specific soil cleanup levels for organic compounds and metals are determined from an environmental fate/transport environmental risk assessment model contained in the Wyoming Water Quaility Rules and Regulations, Chapter XVII, Underground Storage Tanks, Appendix A. Procedures for Establishing Environmental Restoration Standards for Leaking Underground Storage Tank Remediation Actions. Model is similar to ASTM RBCA.

Contact: LeRoy Feusner, Department of Environmental Quality 307-777-7781

APPENDIX F

COST FACTORS

F-1 Introduction

The information in this appendix is taken largely from the Thermal Desorption Applications Manual for Treating Nonhazardous Petroleum Contaminated Soils (unpublished, Troxler et. al., 1992), developed for EPA under Contract No. 68-C9-0033 by William Troxler, James Cudahy, *Richard Zink (Focus Environmental) and Seymour Rosenthal (Foster Wheeler Enviresponse). Although modified somewhat for incorporation into this document, the information is used with the permission of Focus Environmental and the U.S. EPA.*

This appendix contains two tables that provide backup reference for some of the cost-estimating information presented in Section 5.4. Table F-1 includes a detailed list of equipment characteristics and a range of site-specific cost factors for both mobile and stationary thermal desorption systems that are popular in the industry. Cost factors are characterized as low, medium, and high values. Table F-1 presents guidelines for selecting which of the three ranges of factors may be most appropriate for a given project application.

Table F-2 lists the assumptions used to develop the cost curves presented in Figures 5-1 through 5-4 of Section 5.4.3 of the Application Guide. These factors were used to calculate the unit project cost ($/ton of contaminated soil) for various sizes (1 to 50,000 tons) for using mobile treatment systems. Soil transport distance (0 to 200 miles) was used as the independent parameter for developing the cost curves for using thermal treatment services at a stationary facility.

Table F-1

FACTORS USED IN ESTIMATING THERMAL DESORPTION COSTS[(a)]

Factor No.	Factors	Range of Values Low	Medium	High	Comments
1.0	**EQUIPMENT CAPACITY FACTORS**				
1.1	Mobile rotary dryer primary burner thermal duty (MM Btu/hr)	5-15	15-30	25-50	Low value is for small system (5-foot-diameter, 18-foot-long dryer) that fits on 1 to 2 trailers. Medium value is for medium sized system (6-foot-diameter, 24-foot-long dryer) that fits on 3 to 6 trailers. High value is for large system (7-foot-diameter, 34-foot-long dryer) that fits on 7 to 10 trailers.
1.2	Mobile rotary dryer afterburner thermal duty (MM Btu/hr)	5-15	15-30	30-50	Low value is for small system that fits on 1 to 2 trailers. Medium value is for medium sized system that fits on 3 to 6 trailers. High value is for large system that fits on 7 to 10 trailers.
1.3	Mobile thermal screw hot oil heater primary burner thermal duty (MM Btu/hr)	5-10	10-15	15-30	Low value is for single 24-inch-diameter by 24-foot-long screw. Medium value is for double screws with same dimensions. High value is for quad screws with same dimensions.
1.4	Stationary rotary dryer primary burner thermal duty (MM Btu/hr)	30-50	50-75	75-120	Low value is for 7-foot-diameter, 32-foot-long. Medium value is for dryer 8-foot-diameter, 36-foot long dryer. High value is for 10-foot-diameter, 40-foot long dryer.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
1.5	Stationary rotary dryer afterburner thermal duty (MM Btu/hr)	30-50	50-75	75-120	Low value is for 7-foot-diameter, 32-foot long dryer. Medium value is for 8-foot diameter, 36-foot long dryer. High value is for 10-foot-diameter, 40-foot long dryer.
2.0	**SCHEDULE FACTORS**				
2.1	Soil treatment rate (tons/hour)	3	10-50	100	Soil treatment capacity depends on system size and soil characteristics.
2.2	Weekly operating schedule (days/week)	5	5	7	Depends on number of operating crews available.
2.3	Daily operating schedule (hours/day)	8	12-16	24	Depends on number of operating crews available.
2.4	Process operating factor (fraction of time that soil processing is conducted relative to scheduled operating time).	0.5	0.75	0.85	Depends on maintenance practices and normal operating schedule. Systems that operate less than 24 hours per day can do some maintenance on off shifts and minimize unplanned downtime.
2.5	Equipment transportation time (days/site)	0.50-1	1-2	3-5	Low value is for moves of less than 100 miles. Medium value is for moves of 100 up to 500 miles. High value is for moves of more than 500 miles. Applicable only for mobile systems.
2.6	Equipment mobilization time (days/site)	0.50-1	1-2	3-7	Time required to set up equipment so that it is operational. Low value is for 1 to 2 trailer system, medium value is for 3 to 6 trailer system, high value is for 7 to 10 trailer system. Applicable only for mobile systems.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
2.7	Equipment demobilization time (days/site)	0.50-1	1-2	3-7	Time required to disassemble equipment and prepare it for transport. Low value is for 1 to 2 trailer system, medium value is for 3 to 6 trailer system, high value is for 7 to 10 trailer system. Applicable only for mobile systems.
2.8	Unsold time between projects (days/site)	0	1-10	No limit	Depends on market conditions. Applicable only for mobile systems.
3.0	**CAPITAL COSTS**				
3.1	Capital cost - mobile systems (MM $)	0.75 to 1.00	1.00 to 1.50	1.50 to 2.00	Low cost is for small (1-2 trailer) system. Medium cost is for medium-sized system that fits on 3-6 trailers. High cost is for large (7-10 trailer) system Includes equipment purchase costs.
3.2	Capital cost - stationary rotary dryer systems, including afterburner (MM $)	2.00 to 2.50	2.25 to 2.75	2.50 to 3.00	All stationary system costs include land, site design, site preparation, storage building, office building, equipment purchase, operational plans, operator training, permitting, equipment erection, and performance testing. Low cost is for 7-foot-diameter, 32-foot-long dryer. Medium cost is for 8-foot-diameter, 36-foot-long dryer. High cost is for 10-foot-diameter, 40-foot-long dryer.
3.3	Capital cost - stationary asphalt plant aggregate dryer systems, excluding afterburner (MM $)	1.75 to 2.00	2.00 to 2.25	2.25 to 2.75	Includes same items as listed for Factor 3.2. Does not include afterburner.
3.4	Interest rate (%)	7-8	9-10	11-12	Depends on current economic conditions and contractor's financial rating. Typical value is approximately two points above the current prime interest rate.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
3.5	Capital recovery period (years)	3-4	5-7	8-10	Depends on equipment owner's estimate of life of equipment and life of market.
3.6	Capital recovery factor (fraction)	-	-	-	Function of interest rate and capital recovery period.
4.0	**SITE FACTORS**				
4.1	Site owner's lost profit while site is out of service ($/day)	0	500-750	500-1,100	Low value is for abandoned gasoline station. Medium value is for gasoline station in busy location. High value is for convenience store with multiple gasoline pumps.
5.0	**PROCUREMENT**				
5.1	Thermal treatment contractor procurement ($/site)	2,000	4,000	6,000	
5.2	Soil transportation contractor procurement ($/site)	500	1,000	1,500	
6.0	**REGULATORY COMPLIANCE AUDIT**				
6.1	Thermal treatment contractor ($/site)	1,000	2,000	4,000	
6.2	Soil transportation contractor ($/site)	100	500	1,000	
7.0	**PLANNING/SITE DESIGN**				
7.1	Equipment Transportation Plan	0	500	2,000	Most planning and procurement items for mobile applications are one-time costs that are included in capital cost, with the possible exceptions of site-specific environmental monitoring plan and health and safety plan.
7.2	Mobilization/Demobilization Plan	0	1,000	5,000	
7.3	Health and Safety Plan	0	1,000	5,000	
7.4	Sampling and Analysis Plan	0	2,000	5,000	
7.5	Community Relations Plan	0	1,000	5,000	
7.6	Operations Plan	0	5,000	10,000	
7.7	Environmental Monitoring Plan	0	3,000	5,000	
7.8	Site Security Procedures	0	500	1,000	
7.9	Soil pre-acceptance testing	0	1,000	2,000	
7.10	Soil treatability testing	0	2,000	5,000	
7.11	Treated soil stability testing	0	500	2,000	

Factor No.	Factors	Range of Values Low	Medium	High	Comments
8.0	**PERMITTING**				
8.1	Permitting cost ($/site)	0 to 3,000	3,000 to 10,000	10,000 to 200,000	Lowest cost would be incurred for a mobile system in a state where a permit has previously been received and only a site-specific air permit is required. Highest cost would be incurred for a mobile system to obtain initial permits in states where multiple permits are required and/or a performance test must be conducted at a site.
9.0	**SITE PREPARATION**				
9.1	Grading and drainage	0	0	4,000	Normally set up system in existing parking lot or other paved area that requires little or no site preparation costs. Cost applicable only for mobile systems.
9.2	Foundations and pads	0	0	8,000	
9.3	Access roads and parking	0	0	8,000	
9.4	Water connection	1,000	2,000	4,000	
9.5	Natural gas connection	0	0	4,000	
9.6	Electrical connection	0	0	4,000	
10.0	**EQUIPMENT MOBILIZATION/ERECTION**				
10.1	No. of trailers of equipment	1-2	3-6	7-10	Low value is for small system with capacity of 0 to 15 tons per hour. Medium value is for system with capacity of 15 to 30 tons per hour. High value is for large system with capacity of 40 to 60 tons per hour. Applicable only for mobile systems.
10.2	Equipment transportation unit cost ($/trailer/mile)	4.00	5.00	9.00	Varies depending on size of trailer. High estimate is for oversize trailers that require escorts and special permits. Applicable only for mobile systems.
10.3	Equipment Erection ($/site)	-	-	-	Applicable only to mobile systems. Erection costs for stationary systems are included in capital costs.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
11.0	**PERFORMANCE TESTING**				
11.1	State air test execution cost ($/site)	0	0	25,000 - 150,000	Normally required only once per state or once per air quality management district for mobile systems. High cost estimate range depends on state air testing requirements
12.0	**TREATMENT OPERATIONS**				
12.1	Soil treatment operations ($/ton)	-	-	-	Costs are estimated as capital costs (Factor 3.0), labor (Factor 13.0), travel and expenses (Factor 14.0), health and safety (Factor 15.0) maintenance (Factor 16.1), overhead (Factor 16.2), insurance (Factor 16.3), fuel and utilities (Factor 17.0), waste treatment and disposal (Factor 18.0), and analytical costs (Factor 20.0).
13.0	**LABOR**				
13.1	No. of operating crews	1-2	2-3	3-4	Number of crews required depends on operating schedule (days/week and hours/day). Calculate number of crews based on 40 to 48 working hours per week per crew.
13.2	Operating crew size (persons)	3	5	7	Depends on equipment size and complexity and soil processing rate. Low value is for 1 to 2 trailer mobile system. Medium value is for 3 to 6 trailer mobile system. High value is for 7 to 10 trailer mobile system.
13.3	Average salary/fringes unit cost ($/operator/year)	31,200	41,600	52,000	Includes salary and 30% fringe benefits. Low cost assumes labor rate in non-urban area, medium value assumes urban area labor rate. High value assumes urban area labor rate and 8 hours/week overtime.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
14.0	**TRAVEL AND EXPENSES**				
14.1	Travel and expenses unit cost ($/operator/week)	0	350	600	Low value assumes local operations, no travel required. Medium value assumes regional operation, hotel, food, and automobile expenses only. High value assumes remote operation requiring air fare, hotel, food, and automobile expenses required. Applicable only for mobile systems.
15.0	**HEALTH AND SAFETY**				
15.1	Health and safety supplies unit cost ($/operator/week)	0	10	20	Low value assumes no health and safety services provided by contractor. Medium value assumes safety equipment (hard hat, shoes, coveralls, respirator, hearing protection) provided by contractor. High value assumes safety equipment and annual physicals provided by contractor.
16.0	**MAINTENANCE, OVERHEAD, AND INSURANCE**				
16.1	Maintenance unit cost ($/ton of soil feed)	3.00	5.00	8.00	Maintenance cost depends on design and mechanical complexity of equipment and age of equipment. Maintenance cost includes spare parts and third party labor.
16.2	Overhead unit cost (% of capital cost per year)	15	20	40	Includes home office engineering, marketing, accounting, legal, and other support functions.
16.3	Insurance unit cost (% of capital cost per year)	5	7.5	10	Depends on type of policy, coverage limits, and design of equipment.
17.0	**FUEL AND UTILITIES**				
17.1	Natural gas unit cost a. ($/MM Btu) b. ($/1000 scf)	 2.06 2.00	 2.68 2.60	 4.64 4.50	Cost depends on market conditions and geographical location. Cost assumes natural gas with a heating value of 1,030 Btu/scf.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
17.2	Propane unit cost a. ($/MM Btu) b. ($/gal)	 5.45 0.50	 6.00 0.55	 7.64 0.70	Cost depends on market conditions and geographical location. Cost assumes 4.25 lb/gal, 21,500 Btu/lb.
17.3	No. 2 fuel oil unit cost a. ($/MM Btu) b. ($/gal)	 4.69 0.60	 5.08 0.65	 6.64 0.85	Cost depends on market conditions and geographical location. Cost assumes 7.1 lb/gal, 18,000 Btu/lb.
17.4	Diesel fuel unit cost a. ($/MM Btu) b. ($/gal)	 4.69 0.60	 5.08 0.65	 6.64 0.85	Cost depends on market conditions and geographical location. Cost assumes 7.1 lb/gal, 18,000 Btu/lb.
17.5	Thermal desorber total auxiliary fuel usage (MM Btu/ton of soil feed)	-	-	-	Depends on thermal desorber type, whether an afterburner is used for off-gas treatment, soil type, soil moisture content, petroleum contaminant type, soil contaminant concentration, and soil residual organic criteria.
17.6	Front end loader diesel fuel usage rate (gal/hr)	5-8	8-12	12-15	Low cost is loader with 0.5-cubic yard bucket. Medium cost is for loader with 1.0-cubic yard bucket. High cost is loader with 2.0-cubic yard bucket.
17.7	No. of front end loaders	1	2	2	Normally provide one front end loader for handling contaminated soil and 1 loader for handling treated soil in order to prevent cross contamination. One loader may be sufficient if treated soil is loaded directly into trucks or stockpiled with conveyor system.
17.8	Electrical generator diesel fuel usage rate (gal/hr)	5-6	8-12	12-18	Low cost is for 50-Kw generator. Medium cost is for 100-kW generator. High cost is for 200-kW generator.
17.9	Water unit cost ($/gal)	0.0005	0.001	0.002	Cost based on connection to public utility supply. Cost is site specific.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
17.10	Water usage for cooling treated soil (gal/ton of soil feed)	40	50	60	Low value based on cooling soil from 450°F to 200°F (typical treatment temperature for gasoline or other light hydrocarbons). Typical value based on cooling soil from 650°F to 200°F (typical treatment temperature for No. 2 fuel oil). High value based on cooling soil from 950 °F to 200 °F (typical treatment temperature for No. 6 fuel oil). All values calculated based on water evaporated plus 15% residual moisture in treated soil.
17.11	Water usage for gas quenching, assuming system uses an after-burner (gal/ton of soil feed)	60	70	80	Low value based on afterburner exit gas at 1,400°F quenched to 500°F. Typical value based on afterburner exit gas at 1,400°F quenched to 350°F. High value based on afterburner exit gas at 1,600°F quenched to 350°F. Water quench cost incurred only for systems with wet scrubbers or systems where baghouse follows afterburner.
17.12	Electricity unit cost ($/Kw-hr)	0.045	0.06	0.08	Costs based on typical ranges of public utility electrical supply.
17.13	Electricity usage (kW-hr/ton of soil feed)	0.50	1.0	2.0	Low value based on indirectly heated system (thermal screw). Medium value based on directly heated system without an afterburner (asphalt plant aggregate dryer). High value based on directly heated system with an afterburner (rotary dryer). Factor not used if electricity supplied by diesel generator.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
18.0	**WASTE TREATMENT/DISPOSAL**				
18.1	Aqueous- phase activated carbon unit cost ($/lb of carbon)	1.40	1.50	2.00	Cost depends on purchase quantity. Low cost is based on > 30,000 pound purchase. High cost is based on < 500 pound purchase. Costs include virgin carbon purchase, delivery, regeneration, and spent carbon transportation cost. Cost is incurred only for systems with condensation-type off-gas treatment train.
18.2	Aqueous-phase activated carbon usage (lb/ton of soil feed)	1.00	2.50	7.50	Low value based on 1,000 ppm of organic contamination in soil. Medium value is based on 5,000 ppm organic contamination in soil. High value based on 15,000 ppm organic contamination in soil. Cost incurred only for systems with condensation-type off-gas treatment train.
18.3	Vapor-phase activated carbon unit cost ($/lb of carbon)	2.35	2.50	3.05	Cost depends on purchase quantity. Low cost is based on > 30,000 pound purchase. High cost is based on < 500 pound purchase. Costs include virgin carbon purchase, delivery, regeneration, and spent carbon transportation costs. Cost incurred only for systems with condensation-type off-gas treatment train.
18.4	Vapor-phase activated carbon usage (lb/ton of soil feed)	1.00	2.50	7.50	Low value based on 1,000 ppm of organic contamination in soil. Typical value based on 5,000 ppm organic contamination in soil. High value based on 15,000 ppm organic contamination in soil. Cost incurred only for systems with condensation-type off-gas treatment train.
18.5	TPH concentration in soil feed (%)	0.5	1.0	3.0	Value is site specific.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
18.6	Condenser efficiency (fraction)	0.90	0.95	0.98	Depends on discharge temperature of condenser, gas discharge temperature of thermal desorber, and type of petroleum product. Low value assumes condenser outlet temperature of 140°F. Medium value assumes condenser outlet temperature of 90°F. High value assumes condenser outlet temperature of 40°F. Applicable only to systems that used condensation type air pollution control trains.
18.7	Phase separator efficiency (fraction)	0.95	0.98	0.99	Depends on petroleum hydrocarbon type. Low value assumes gasoline, medium value assumes No. 2 fuel oil, high value assumes No. 6 fuel oil.
18.8	Organic liquids unit disposal cost ($/lb of organic)	0	0.045	0.06	Low value is based on recycling to petroleum refinery (may be applicable for on-site treatment at refineries). Medium to high values are based on disposal by a fuel blending company. Cost incurred only for systems with condensation-type off-gas treatment train.
18.9	Organic liquids transportation unit cost ($/ton-mile)	0.12	0.15	0.20	Value depends on quantity of waste. Minimum value will be incurred for truckload quantities of wastes. Higher values will be incurred for partial loads. Cost incurred only for systems with condensation-type off-gas treatment train.
18.10	Treated soil disposal unit cost ($/ton of soil feed)	0	0	10-25	Soil is normally used for road base material, landfill cover, or clean fill at no disposal cost. High estimate is based on landfilling soil in a sanitary landfill. Cost incurred only for stationary systems. Assume soil backfilled on site for mobile system applications.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
19.0	**SOIL TRANSPORTATION**				
19.1	Soil transportation unit cost ($/ton/mile)	0.08	0.10	0.12	Cost depends on geographical area, extent of traffic congestion, and hauling distance. Unit costs are highest for short (< 25 miles) hauling distances. Cost incurred only for stationary systems.
20.0	**ANALYTICAL**				
20.1	TPH analysis unit cost, EPA Method 418.1 ($/sample)	50	80	150	Cost depends on number of samples and turnaround requirements. Lowest cost will be for multiple samples and standard turnaround times. Highest cost will be for single samples and expedited (<5 day) turnaround times.
20.2	BTEX analysis unit cost, EPA Method 8020 ($/sample)	50	110	175	Cost depends on number of samples and turnaround requirements. Lowest cost will be for multiple samples and standard turnaround times. Highest cost will be for single samples and expedited (<5 day) turnaround times.
20.3	Other parameters analyses unit costs ($/sample)				Cost depends on number of samples and turnaround requirements. Lowest cost will be for multiple samples and standard turnaround times. Highest cost will be for single samples and expedited (<5 day) turnaround times.
	Chemical parameters: Total Petroleum Hydrocarbons (TPH), EPA Modified Method 8015	100	120	180	
	Nonhalogenated Volatile Organics (TPH), EPA Modified Method 8015	100	120	180	
	Halogenated Volatile Organics (PCBs), EPA Method 8080	200	250	350	
	TCLP extraction: volatiles, semivolatiles, pesticides/ and metals (EPA Method 1311)	100	185	250	

Factor No.	Factors	Range of Values Low	Medium	High	Comments
	TCLP analyses: Volatile Organics, EPA Method 8240	250	330	450	
	Semivolatile Organics, EPA Method 8270	250	630	900	
	Pesticides/herbicides, EPA Method 8080/8150	200	350	500	
	Metals (Ag, As, Ba, Cd, Cr, Hg, Pb, Se) EPA Methods 6010/7000	160	165	240	
	All 39 TCLP parameters, including extractions	650	1,400	2,100	
	Geotechnical parameters: Compressive strength (remolded), ASTM Method D-2166	120	180	240	
	Consolidation test, ASTM Method D-2435	350	500	750	
	Soil Classification (USCS), ASTM Method D-2487	175	250	375	
	Soil moisture, ASTM Method D-2216	20	30	50	
	Bulk density, ASTM Method D-1556, ASTM Method D-2922, ASTM Method D-2167	50	75	125	
20.4	No. TPH analytical samples (No. samples/100 tons of soil feed)	0.1	0.5	1.0	Depends on state and local regulatory requirements.
20.5	No. BTEX analytical samples (No. samples/100 tons of soil feed)	0.1	0.5	1.0	Depends on state and local regulatory requirements.
20.6	No. other parameters analytical samples (No. samples/100 tons of soil feed)	0.1	0.5	1.0	Depends on state and local regulatory requirements.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
21.0	**EQUIPMENT DEMOBILIZATION**				
21.1	Equipment decontamination, disassembly, and removal	-	-	-	Applicable only to mobile systems.

Factor No.	Factors	Range of Values Low	Medium	High	Comments
22.0	**SITE CLOSURE**				
22.1	Site closure notification ($/site)	1,000	1,500	2,000	Low value assumes UST site with <1,000 tons of soil, Medium value assumes UST site with 1,000 to 2,000 tons of soil, High value assumes site with 2,000 to 10,000 tons of soil.
22.2	Verification sampling and analysis ($/site)	5,000	6,000	7,000	
22.3	Closure record preparation ($/site)	1,000	1,500	2,000	
22.4	Remove personnel support facilities ($/site)	0	0	500	
22.5	Remove access roads and parking ($/site)	0	0	500	
22.6	Site restoration ($/site)	5,000	6,000	8,000	
23.0	**PROFIT**				
23.1	Contractor's profit (% of project cost)	10	15	20	Value depends on project size, economic conditions, and extent of local competition.

(a) Cost factors indexed to December 1992 basis.

Table F-2.
Assumptions Used in Cost Estimates for Thermal Desorption Systems

Unit Cost Factor	Mobile Systems: Small Rotary Dryer	Mobile Systems: Large Rotary Dryer	Mobile Systems: Thermal Screw	Fixed-Base System: Rotary Dryer
SOIL FACTORS				
USCS soil category	MH	MH	MH	MH
Soil moisture content (%)	10, 20, 30	10, 20, 30	10, 20, 30	10, 20, 30
CONTAMINANT CHARACTERISTICS				
Contaminant type	No. 2 Fuel oil	No. 2 Fuel oil	No. 2 Fuel oil	No. 2 Fuel oil
Contaminant TPH concentration (%)	0.3	0.3	0.3	0.3
SOIL TREATMENT CRITERIA				
Soil treatment criteria for TPH (mg/kg)	100	100	100	100
EQUIPMENT CAPACITY FACTORS				
Rotary dryer primary burner thermal duty (MM Btu/hr)	10	40	NA	40
Asphalt plant aggregate dryer burner thermal capacity - assumes no afterburner (MM Btu/hr)	NA	NA	NA	NA
Thermal screw hot oil heater burner thermal capacity (MM Btu/hr)	NA	NA	12	NA
Afterburner exit gas temperature (°F)	1,400	1,400	NA	1,400
SCHEDULE FACTORS				
Estimated soil treatment rate (tons/hour of feed soil)	8	31	11	31
Site size (tons of feed soil)	1,000 to 10,000	500 to 10,000	500 to 10,000	NA
Weekly operating schedule (days/week)	5	5	5	7
Daily operating schedule (hours/day)	16	16	16	24
Process operating factor (fraction)	0.75	0.75	0.75	0.85
Equipment transportation time (days/site)	1	2	1	NA

Unit Cost Factor	Mobile Systems Small Rotary Dryer	 Large Rotary Dryer	 Thermal Screw	Fixed-Base System Rotary Dryer
Equipment mobilization time (days/site)	0.5	5	3	NA
Equipment demobilization time (days/site)	0.5	5	3	NA
Unsold time between projects (days/site)	5	10	5	NA
CAPITAL COSTS				
Capital cost - mobile systems	900,000	1,750,000	900,000	NA
Capital cost - fixed-base systems	NA	NA	NA	2,500,000
Interest rate (%)	10	10	10	10
Capital recovery period (years)	7	7	7	7
Capital recovery factor	0.2054	0.2054	0.2054	0.2054
SITE FACTORS				
Site owner's retail activities lost profit ($/day)	0	0	0	0
PROCUREMENT				
Thermal treatment contractor ($/site)	0	0	0	0
Soil transportation contractor ($/site)	0	0	0	0
REGULATORY COMPLIANCE AUDIT				
Thermal treatment contractor ($/site)	0	0	0	0
Soil transportation contractor ($/site)	0	0	0	0
PLANNING/SITE DESIGN				
Equipment transportation plan cost ($/site)	0	0	0	NA
Mobilization/demobobilization plan cost ($/site)	0	0	0	NA
Health and safety plan cost ($/site)	1,000	1,000	1,000	(b)

Unit Cost Factor	Mobile Systems: Small Rotary Dryer	Mobile Systems: Large Rotary Dryer	Mobile Systems: Thermal Screw	Fixed-Base System: Rotary Dryer
Sampling and analytical plan cost ($/site)	0	0	0	(b)
Community relations plan cost ($/site)	0	0	0	(b)
Operations plan cost ($/site)	0	0	0	(b)
Environmental monitoring plan cost ($/site)	3,000	3,000	3,000	(b)
Site security procedures cost ($/site)	0	0	0	(b)
Soil pre-acceptance testing ($/site)	1,000	1,000	1,000	0
Soil treatabillity testing cost ($/site)	0	0	0	0
Treated soil stability testing ($/site)	0	0	0	0
PERMITTING				
Permitting cost ($/site)	6,000	6,000	6,000	(b)
SITE PREPARATION				
Grading and drainage cost ($/site)	0	0	0	(b)
Foundations and pads cost ($/site)	0	0	0	(b)
Access roads and parking cost ($/site)	0	0	0	(b)
Water connection cost ($/site)	1,000	2,000	1,000	(b)
Natural gas connection cost ($/site)	0	0	0	(b)
Electrical connection cost ($)	0	0	0	(b)
EQUIPMENT MOBILIZATION/ERECTION				
No. of trailers of equipment	1	10	3	NA
Equipment transportation cost ($/trailer/mile)	5.00	9.00	5.00	NA
Equipment transportation distance (miles)	200	200	200	NA

	Mobile Systems			Fixed-Base System
Unit Cost Factor	**Small Rotary Dryer**	**Large Rotary Dryer**	**Thermal Screw**	**Rotary Dryer**
PERFORMANCE TESTING				
State air test execution ($/site)	0	0	0	(b)
LABOR				
No. of operating crews	2	2	2	4
Operating crew size (persons)	4	6	4	6
Average salary/fringes unit cost ($/operator/year)	41,600	41,600	41,600	41,600
TRAVEL AND EXPENSES				
Travel and expenses cost ($/operator/week)	350	350	350	NA
HEALTH AND SAFETY				
Health and safety supplies unit cost ($/operator/week)	10	10	10	10
MAINTENANCE, OVERHEAD, INSURANCE				
Maintenance unit cost ($/ton of feed material)	5.00	5.00	5.00	5.00
Overhead cost (% of capital cost/year)	20	20	20	20
Insurance cost (% of capital cost/year)	7.5	7.5	7.5	7.5
FUEL AND UTILITIES				
Thermal desorber total auxiliary fuel usage (including afterburner if applicable) (MM Btu/ton of feed soil)	1.58	1.58	0.84	1.58
Thermal desorber auxiliary fuel unit cost ($/MM Btu)	5.08	5.08	5.08	5.08
Front end loader diesel fuel unit cost ($/gal)	0.65	0.65	0.65	0.65
Front end loader diesel fuel usage rate (gal/hr)	5	10	5	10
No. of front end loaders	2	2	2	2

Unit Cost Factor	Mobile Systems Small Rotary Dryer	 Large Rotary Dryer	 Thermal Screw	Fixed-Base System Rotary Dryer
Electrical generator diesel fuel unit cost ($/gal)	0.65	0.65	0.65	0.65
Electrical generator diesel fuel usage rate (gal/hr)	5	10	2	NA
Water unit cost ($/gal)	0.001	0.001	0.001	0.001
Water usage for cooling treated soil (gal/ton of feed soil)	50	50	50	50
Water usage for gas quenching (gal/ton of feed soil)	NA	NA	NA	NA
Electricity unit cost ($/kW-hr)	NA	NA	NA	0.06
Electricity usage (kW-hr/ton of feed soil)	(c)	(c)	(c)	2.0
Aqueous phase activated carbon unit cost ($/lb of carbon)	NA	NA	1.50	NA
Aqueous phase activated carbon usage rate (lb/ton of feed soil)	NA	NA	2.50	NA
Vapor phase activated carbon unit cost ($/lb of carbon)	NA	NA	2.50	NA
Vapor-phase activated carbon usage rate (lb/ton of feed soil)	NA	NA	2.50	NA
TPH concentration in feed soil (%)	0.3	0.3	0.3	0.3
Condenser efficiency (fraction)	NA	NA	0.95	NA
Phase separator efficiency (fraction)	NA	NA	0.98	NA
Organic liquid unit disposal cost ($/lb of organic)	NA	NA	0.045	NA
Organic liquid transportation unit cost ($/ton/mile)	NA	NA	0.15	NA
Organic liquid transportation distance for disposal (miles)	NA	NA	500	NA
Treated soil unit disposal cost ($/ton of feed soil)	NA	NA	NA	10

Unit Cost Factor	Mobile Systems Small Rotary Dryer	 Large Rotary Dryer	 Thermal Screw	Fixed-Base System Rotary Dryer
SOIL TRANSPORTATION				
Soil transportation unit cost ($/ton/mile)	NA	NA	NA	0.10
Contaminated soil transportation distance (miles)	NA	NA	NA	0 to 200
Treated soil transportation distance (miles)	NA	NA	NA	0
ANALYTICAL				
TPH analysis unit cost, EPA Method 418.1 ($/sample)	80	80	80	80
BTEX analysis, EPA Method 8020 ($/sample)	110	110	110	110
Other parameters analyses ($/sample)	1,050	1,050	1,050	1,050
No. TPH analytical samples (No. samples/100 tons of feed soil)	0.5	0.5	0.5	0.5
No. BTEX analytical samples (No. samples/100 tons of feed soil)	0.5	0.5	0.5	0.5
No. other parameters analyses samples (No. samples/100 tons of feed soil)	0.1	0.1	0.1	0.1
SITE CLOSURE				
Site closure notification cost ($/site)	0	0	0	0
Verification sampling/analysis cost ($/site)	0	0	0	0
Closure record preparation cost ($/site)	0	0	0	0
Removal personnel support facilities cost ($/site)	0	0	0	0
Remove access roads and parking cost ($/site)	0	0	0	0

Unit Cost Factor	Mobile Systems: Small Rotary Dryer	Mobile Systems: Large Rotary Dryer	Mobile Systems: Thermal Screw	Fixed-Base System: Rotary Dryer
Site restoration cost ($/site)	0	0	0	0
PROFIT				
Contractor's profit (% of total cost)	20	20	20	20

NA - Not applicable
(a) Data used to develop cost curves presented in Figures 5-1 through 5-4 in Section 5.
(b) Included in capital costs.
(c) Based on using electricity from diesel generator.

APPENDIX G

TYPICAL PROJECT TASKS

G.1 Introduction

This appendix presents a list of typical tasks that might be involved in a thermal desorption project. The list (Table G-1) is not meant to be all inclusive, but is representative of the tasks involved and is a combination of tasks to be performed by the Navy and their potential subcontractors. Tasks to be performed by the subcontractors have not been identified in this list because the exact division of work may be different for each project.

This list also assumes that the decision has already been made to use thermal desorption and to subcontract the work to a thermal treatment vendor. Therefore, the list begins with site design and not with site investigation and feasibility studies.

A significant portion of this Appendix was taken from Thermal Desorption Applications Manual for Treating Nonhazardous Petroleum Contaminated Soil (Troxler et al., 1992) and was modified to fit this Guide.

1.0 PRELIMINARY SITE DESIGN

1.1	Check zoning ordinances	Check local zoning ordinances, considering fire codes, noise restrictions, setback requirements, or other restrictions affecting the operation of industrial equipment. Confirm that on-site thermal desorption treatment is permissible with local and state regulators.
1.2	Site characterization	Characterize the type and extent of contamination. Develop drawings illustrating contaminated areas.
1.3	Preliminary site layout	Develop drawings illustrating approximate areas for excavation (if needed), material handling and storage, thermal treatment, treated material storage, support areas, decontamination areas, etc. Determine if sufficient area is available to operate equipment and stockpile contaminated and treated soils. Define location of utility tie-in points. Obtain site map to develop site layout drawings.
1.4	Develop technical bid specifications document for thermal desorption contractor	Include description of the following: – Detailed description of scope of work, including limits of work – Site characterization data (i.e., maximum size of material to be treated, type and quantity of debris (rocks, wood, etc.)) – Type and concentrations and in situ distribution of contaminants – Soil classification, moisture content – Source of contamination, such as gasoline station tank, transportation spill, etc. – Estimated quantity of soil (cubic yards, tons) – Analytical test results and soil boring logs, if available – Results from earlier investigations – Treated soil cleanup criterion (mg/kg) for each parameter – Requirements for disposal or backfill of

		treated soil – Analytical methods to be used for each required parameter – Air emission limits and testing requirements, if any – Water discharge limits – Criteria for off-site disposal of residuals, if any – Description of all interface points
1.5	Develop bid form (See Section 6.3 of main document for more information)	Bid sheet should include: – Mobilization/demobilization costs – Soil treatment cost ($/ton) – Pre-acceptance sampling/analysis ($/sample) – Treated soils sampling/analysis ($/sample) – Other contractor activities – Obtain lump sum pricing for all well-defined activities
1.6	Develop Preliminary Site Work Plan	Develop Plan describing preliminary approach to how the project is expected to be performed and the baseline schedule for the project. This Plan should be revised after selection of a contractor.
1.7	Develop other preliminary site plans	Other plans that may be needed include: - Health and Safety Plan - Sampling and Analysis Plan - Community Relations Plan - Environmental Regulatory Compliance Plan - Site Security Plan - Quality Assurance/Quality Control Plan - Transportation and Disposal Plan
2.0	**PROCUREMENT**	
2.1	Thermal desorption contractor pre-qualification	Identify potential contractors with the type of thermal desorption systems that may be used at this site. Determine if prior experience within

		the state where site is located is important. Conduct phone survey to determine characteristics of soil that can be treated by each contractor, such as petroleum product type and contaminant concentrations. Verify that characteristics of contaminated soils are within treatability criteria for each contractor. Verify that the contractors have or are able to obtain all of the required state and local permits to receive and treat the type of contamination found at this site. Determine schedule allowed for contractor to treat soil. Develop short list of pre-qualified contractors that can meet all project objectives.
2.2	Develop Bid Package	Develop Bid Package for Thermal Treatment Bidders, including Instructions to Bidders, Statement of Work (SOW) or Specifications developed above with applicable drawings, the schedule to complete the project, and Example Contract.
2.3	Solicit thermal desorption bids	Select potential bidders and issue request for quotation.
2.4	Perform site walk	Require Bidders to be present for site walk. Review condition of site, including contaminated areas and support areas.
2.5	Evaluate Bids	Evaluate Bids received and rank in order of preference. Interview Bidders to resolve questions. Obtain “Best And Final Offer” (BAFO), if needed.
2.6	Contract award	Award contract, contingent upon satisfactory completion of regulatory compliance audit as described below.
3.0	**REGULATORY COMPLIANCE AUDIT**	Perform audit of potential thermal desorption systems to determine regulatory compliance status and management practices of contractor (optional).
3.1	Environmental permits	Permits for mobile thermal desorption systems are likely to have site-specific requirements. Review existing permits to determine process

		operating limits and record-keeping requirements.
3.2	Monitoring records	Review performance test and monitoring records to determine compliance with permit conditions, completeness of records.
3.3	Soil treatment certification	Verify that documents are issued to generator certifying soil was treated to meet parameters specified in facility permit.
3.4	Permit compliance performance	Contact regulatory agencies and review contractor's permit compliance performance.
3.5	Insurance	Review contractor's limits on general liability insurance, workmen's compensation insurance, and automobile liability insurance.
4.0	**DETAILED PLANNING AND FINAL SITE DESIGN**	Finalize Preliminary Plans developed earlier. Some or all of these plans or tasks may be provided by the Thermal Desorption Contractor.
4.1	Develop Site Work Plan	Finalize Plan describing how project will be performed.
4.2	Develop Mobilization/Demobilization Plan	Develop preliminary plan for sequencing delivery of equipment to site and removing equipment from site.
4.3	Develop Health and Safety Plan	Develop Health and Safety Plan.
4.4	Develop Sampling and Analysis Plan	Plan to monitor feed material and treated residuals (treated soil, baghouse dust, wastewater) during routine operations. Plan describes sample identification procedures, sampling methods, sampling frequency, sample holding times, sample preparation procedures, analytical parameters, analytical methods, and quality assurance/quality control (QA/QC) requirements in accordance with permit requirements.
4.5	Develop Community Relations Plan	Not normally required for on-site thermal desorption treatment of nonhazardous

		petroleum-contaminated soils. May be desirable for some sites.
4.6	Develop Operations Plan	Plan describing process equipment startup, shutdown, emergency, and normal operating procedures. Plan also describes process controls.
4.7	Develop Environmental Compliance Plan	Site-specific plan to outline regulations that apply to the project, regulatory requirements, and how the project will comply with these requirements.
4.8	Develop Site Security Procedures	May not be required if operating on site that already provides security services.
4.9	Soil pre-acceptance testing verification	Requirements are site and contractor specific. Review results of testing conducted during site investigations to verify that soil is not a hazardous or toxic material. Conduct any additional testing required to meet thermal desorption system soil pre-acceptance permit requirements. Typical testing parameters include PCBs, RCRA TCLP parameters, metals, and organic halogens. Testing should also be conducted to determine USCS soil classification and soil moisture content.
4.10	Treated soil testing	Testing to confirm treated soils meet cleanup and backfill criteria.
4.11	Develop detailed site layout drawings	Develop site layout drawing to locate process equipment, feedstock pretreatment equipment, water storage tanks, wastewater storage tanks, fuel supply tanks, contaminated soil stockpiles, and treated soil stockpiles.
4.12	Design foundations (if applicable)	Mobile systems normally use hydraulic leveling systems and do not require special foundations. Normally use existing paved area or provide area with 1 foot of compacted gravel cover.
4.13	Design utility system tie-ins	Design connection requirements for all required utilities.

5.0	**PERMITTING**	All or some of these tasks may be performed by the Contractor.
5.1	Identify permit requirements	Requirements vary by location and site conditions. Typical permit requirements for treating nonhazardous petroleum-contaminated soils include a state or local air emission permit. Other permits that may be required include a zoning permit, solid waste permit, wastewater discharge permit, health department permit, fire marshal permit, building inspection permit, and contractor's license.
5.2	Prepare permit applications	Prepare site-specific permit applications.
5.3	Prepare Performance Test Plans	Performance test plan will normally include description of equipment, operating parameters, monitoring procedures, and sampling and analysis procedures.
5.4	Conduct permit reviews	Review permit applications with regulatory agencies.
5.5	Finalize permit applications	Incorporate modifications required by regulatory agency.
5.6	Negotiate final operating permit limits with regulatory agencies and receive agency approval	If Performance Test is required, final permit condition negotiations are conducted after Performance Test results are available.
6.0	**SITE PREPARATION**	
6.1	Grading and drainage	May or may not be required.
6.2	Pour foundations and pads	Not normally required. Normally set system up on gravel area or paved area.
6.3	Construct access roads and parking	May or may not required.
6.4	Water connection from utility to battery limits	Water connection may be required.
6.5	Natural gas connection from utility to battery limits	Mobile systems normally use propane or No. 2 fuel oil as auxiliary fuel, however, natural gas may be used if it readily available.

6.6	Electrical connection from utility to battery limits	Electricity to be brought in from connection point with utility to equipment.
7.0	**EQUIPMENT MOBILIZATION/ ERECTION**	
7.1	Transport process equipment	Number of trailers depends primarily on capacity of systems.
7.2	Conduct site-specific personnel training	Extent of operator training is contractor and site specific.
7.3	Set up support facilities	Office trailer and sanitary facilities.
7.4	Unload equipment	Most items are trailer-mounted, limited equipment unloading required.
7.5	Erect all equipment modules	Assemble system
7.6	Interconnect Instrumentation	Requirements are system specific. Small systems are generally modular and require a minimum of effort to connect and set up equipment.
7.7	Interconnect control systems	Requirements are system specific.
7.8	Interconnect electrical distribution system	Requirements are system specific.
7.9	Interconnect water supply system	Requirements are system specific.
7.10	Interconnect continuous emissions monitoring systems	Requirements are system specific.
7.11	Install environmental monitoring system	Ambient air and wastewater discharge monitoring system may be required at some sites to meet regulatory requirements.
7.12	Set up feedstock pretreatment equipment	Screening or size reduction equipment may be required.
7.13	Set up water supply tanks	Water is required to cool and moisturize the treated soil. Some systems require water to quench the off-gas from the afterburner.

7.14	Set up wastewater treatment system	Requirements are system and site specific.
7.15	Develop contaminated soil stockpile area	Area to be used to stockpile soils prior to treatment and perform any material processing required.
7.16	Develop treated soil stockpile area	Develop area to store treated soils until analytical test results are confirmed. Final soil disposal may require approval of sampling and analysis results by regulatory agencies. Storage area should include provisions for stormwater management and erosion control of stockpiled material.
7.17	Check electrical systems	Continuity checks.
7.18	Check instrumentation systems	Continuity checks, instrumentation calibration.
7.19	Conduct hydrostatic testing	Required for systems that use wet scrubbers, water quench systems, or use water for cooling the treated soil.
7.20	Align rotating equipment	Applicable to rotary dryers.
7.21	Check winterization systems	Depends on climatic conditions.
7.22	Check fire protection systems	Depends on site requirements.
7.23	Check emergency procedures	Check emergency shutdown procedures, check interlocks.
7.24	Start up plant	Perform mechanical shakedown with clean soil.
7.25	Bring process into equilibrium	Feed uncontaminated soil and stabilize process parameters.
8.0	**PERFORMANCE TESTING**	Requirements are state and site specific. Performance testing will usually be required.
8.1	Check process control and emissions monitoring systems	Perform final calibration check.

8.2	Prepare performance test feed material	Select feed material, perform size reduction pretreatment, spike feed with test material (if required) in accordance with requirements of the Performance Test Plan.
8.3	Deploy sampling team	Requirements are site and project specific.
8.4	Execute performance test	In accordance with requirements of approved Performance Test Plan.
8.5	Conduct laboratory analyses of samples	Analyze feed, treated materials, other residuals, and stack gas samples in accordance with requirements of approved Performance Test Plan.
8.6	Prepare report to regulatory agency	In accordance with requirements of approved Performance Test Plan.
8.7	Operate system during agency review of test report	Operate system, under conditional permit requirements, if allowed.
9.0	**TREATMENT OPERATIONS**	
9.1	Analyze soil feedstock	Requirements are contractor and site specific. Typical analytical parameters are TPH, BTEX, RCRA TCLP metals.
9.2	Pre-treat and blend soil feed material	Pre-treat screening or crushing to remove oversize materials. Blend materials to provide consistent feed composition with organic content within specifications of thermal treatment device.
9.3	Thermally treat soils	Operate system within permitted conditions to meet soil treatment criteria.
9.4	Store treated residuals	Store treated residuals (treated soils, baghouse dust, scrubber water, scrubber sludge, condensed water, condensed organics, activated carbon) to prevent transport of soils by wind or runoff.
9.5	Analyze treated residuals	Analytical parameters are site specific. Common analytical parameters include TPH, BTEX, and TCLP metals. If residuals meet

		regulatory criteria, dispose of residuals. If treated residuals do not meet regulatory criteria, re-treat materials.
9.6	Dispose of treated soil from the thermal treatment system	Dispose of treated soil according to regulatory agency guidelines. Regulations may allow for its use as backfill on site, road base material, landfill cover, or fill material.
9.7	Dispose of treated wastewater from gas cleaning and wastewater treatment systems	Normally used to cool soil, creating a closed-loop water system.
9.8	Dispose of residuals from air pollution control and wastewater treatment systems	Analyze and dispose of in accordance with site specific regulations.
10.0	**EQUIPMENT DEMOBILIZATION**	
10.1	Clean and decontaminate equipment	Steam or mechanical cleaning.
10.2	Dispose of decontamination	In accordance with applicable regulatory requirements.
10.3	Disconnect power systems	Requirements are system specific.
10.4	Disconnect electrical systems	Requirements are system specific.
10.5	Disconnect utility systems	Requirements are system specific.
10.6	Disconnect emissions monitoring systems	Requirements are system specific.
10.7	Disassemble process equipment	Requirements are system specific.
10.8	Load and transport equipment	Requirements are system specific.
11.0	**SITE CLOSURE**	
11.1	Prepare site closure notification	Close in accordance with site specific-requirements and regulations.
11.2	Perform verification sampling and analysis	Requirements are site specific. Sampling and analysis must be performed to verify sufficient excavation has been done to remove all contaminated materials with concentrations above site closure standards.

11.3	Prepare closure records	Site owner must maintain records of results of site investigation conducted at closure of UST site. Records must normally be maintained for 3 years.
11.4	Disconnect and remove site utilities	Requirements are site specific.
11.5	Remove personnel support facilities	Office trailer, sanitary facilities.
11.6	Remove access roads and parking areas	Not normally required if operating on developed site.
11.7	Restore site as required	Requirements are site specific. Grading and seeding site may be required.

APPENDIX H

TYPICAL THERMAL DESORPTION SPECIFICATION

H.1 Introduction

The following specification, Section 02289, is an example specification for thermal desorption that was taken from the "Construction Criteria Base (CCB)" database of standard construction/remediation specifications. This set of specifications on CDs is available from:

National Institute of Building Sciences
1090 Vermont Avenue NW
Suite 700
Washington, DC 20005-4905
phone: (202) 289-7800
fax: (202) 289-1092

This specification may be used as a guide in developing specifications for the use of various types of transportable, on-site, thermal desorption systems. Care should be exercised in specifying the operating conditions listed in these specifications to avoid future claims if the unit fails to meet the performance requirements. It may be advisable to avoid specifying any operating conditions and let the vendor develop the conditions necessary for his/her equipment to meet the required performance.

****
DEPARTMENT OF THE ARMY CEGS-02289 (December 1996)
U.S. ARMY CORPS OF ENGINEERS --------------------------

GUIDE SPECIFICATION FOR MILITARY CONSTRUCTION

Includes Text Adjustment Change (Section 01300 Reference) (June 1997)
****

SECTION 02289
REMEDIATION OF CONTAMINATED SOILS BY THERMAL DESORPTION
12/96

****
NOTE: This guide specification covers the requirements for onsite thermal desorption of nonradioactive materials contaminated by hazardous or toxic organic wastes and by petroleum, oil, or lubricants (POL). This guide specification is to be used in the preparation of project specifications in accordance with ER-1110-345-720.
****

PART 1 GENERAL

1.1 REFERENCES

****
NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 122	(1989) Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process
ASTM E 953	(1988; R 1993) Fusibility of Refuse-Derived Fuel (RDF) Ash

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B40.1	(1991) Gauges - Pressure Indicating Dial Type - Elastic Element
ASME BPV IX	(1995; Addenda Dec 1995) Boiler and Pressure Vessel Code; Section IX, Welding and Brazing Qualifications
ASME PTC 19.3	(1974, R 1986) Instruments and Apparatus:

Part 3 Temperature Measurement

AMERICAN WELDING SOCIETY (AWS)

AWS B2.	1984) Welding Procedure and Performance Qualification
AWS D1.1	(1994) Structural Welding Code – Steel

CODE OF FEDERAL REGULATIONS (CFR)

40 CFR PART 264	Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA 450/4-80/023R	(1985) Guideline for Determination of Good Engineering Practice Stack Height

INTERNATIONAL SOCIETY FOR MEASUREMENT AND CONTROL (ISA)

ISA MC96.1	(1982) Temperature Measurement Thermocouples

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 30	(1993) Flammable and Combustible Liquids Code
NFPA 31	(1992) Installation of Oil Burning Equipment
NFPA 54	(1992) National Fuel Gas Code
NFPA 58	(1995) Standard for the Storage and Handling of Liquefied Petroleum Gases
NFPA 70	(1996) National Electric Code
NFPA 82	(1994) Incinerators, Waste and Linen Handling Systems and Equipment
NFPA	(1992) Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST SP 250	(1995) Calibration Service Users Guide

1.2 System Description

The thermal desorption system shall be provided and operated by the Contractor to transfer organic compounds from contaminated materials to a gaseous stream drawn through the system. The system shall consist of a process or series of processes designed to remove organic contaminants from the contaminated materials by heating the soil or sludge matrix. Removal/treatment of organic vapors shall be completed in one or more airpollution control systems.

1.2.1 Design Requirements

The capacity of the system shall be [consistent with the remedial action schedule] [a minimum of [_____] kg/hour ([_____] tons/hour)]. Modifications to the system shall be the Contractor's responsibility; however, no modifications shall be performed without the Contracting Officer's approval.

1.2.1.1 Primary Desorption Chamber
****
NOTE: This paragraph is applicable to rotary kiln technology only. If batch processes are used, remove this paragraph.
****

The primary desorption chamber volatilizes the compounds of concern. The primary chamber shall be [directly-contacts with the primary chamber operated at a pressure lower than atmospheric.] [indirect-contact.] [An inert carrier gas shall be recycled through the desorber and stack emissions treatment system.]

1.2.1.2 Air Pollution Control System Requirements

****
NOTE: If site materials contain PCBs, consider eliminating the use of an afterburner to alleviate permitting problems during construction.
****

The air pollution control system shall contain [an afterburner. The temperature of the afterburner shall be greater than the temperature of the primary chamber] [an adsorption type treatment system] [a condenser] [_____].

1.2.2 Performance Requirements

1.2.2.1 Treatment Criteria

Maximum contaminant concentrations allowed in thermally treated materials shall be as follows:

ORGANIC CONTAMINANT	TREATMENT CRITERIA (mg/kg)
[Trichloroethylene]	[10]
[_____]	[_____]

Materials that do not meet the treatment criteria shall be retreated until the treatment criteria are met.

1.2.2.2 Emission Criteria
****
NOTE: Current federal regulations are not directly applicable to thermal desorption. The designer should perform an air pathway analysis per ETL 1110-1-174 and obtain the state or air quality regional requirements. Include mass or concentration limits, as appropriate.
****

The system shall be designed to prevent exceeding ambient air quality standards as established by the State, and to minimize health risks associated with thermal desorption system emissions, as shown in TABLE 1.

TABLE 1

EXHAUST GAS CRITERIA

COMPONENT	FEDERAL	STATE
organic removal efficiency (minimum %)	[_____]	[_____]
total hydrocarbons	[_____]	[_____]
O^2 (minimum)	[_____]	[_____]
CO	[_____]	[_____]
HCl	[_____]	[_____]
metals	[_____]	[_____]
particulates	[_____]	[_____]

1.2.2.3 Slagging Control

****
NOTE: The treatability study should determine the ash fusion temperature of the feed materials in accordance with ASTM E 953.
****

Slagging shall be minimized by operating at [_____] degrees C ([_____] degrees F) less than the ash fusion temperature of the feed materials, as determined by ASTM E 953.

1.3 SUBMITTALS

****
NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

Indicate submittal classification in the blank space
using "GA" when the submittal requires Government
approval or "FIO" when the submittal is for
information only.
****

Government approval is required for submittals with a "GA" designation; submittals having a "FIO" designation are for information only. The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES.

SD-01 Data

Sequencing and Scheduling; GA.

Thermal desorption system schedule including dates and durations for system mobilization, startup, proof of performance, interim operation, production burn, and demobilization prior to beginning site activities.

Mobilization Plan; GA.

Specific procedures and requirements for on-site placement of the thermal desorption system and its subsystems.

Startup Plan; GA.

Plan identifying instruments requiring calibration and describing the required calibration procedure and tolerances.

Proof of Performance Plan; GA.

List of the proposed operating conditions for process parameters to be continuously monitored and recorded. Detailed descriptions of the proof of performance schedule, operating conditions and parameters, material sources, and required sampling and analyses shall be included.

Operating Plan; GA.

Specific detailed procedures for continued operation of the system, based on the proof of performance results; adjustments for variation in the contaminated material feed shall be included. Schedule of inspection and maintenance procedures and activities shall be included.

Demobilization Plan; GA.

Demobilization plan detailing specific procedures to be used for decontamination of system components, test methods for verification of decontamination, and the schedule for equipment decontamination and removal from the site.

Utilities; FIO.

Peak and average system requirements for electricity, water, wastewater disposal, natural gas and other fuels.

Equipment; GA.

Information on function, design capacity, and expected operational capacity for the following equipment in the thermal desorption system: feed preparation equipment, feed/treated materials conveying equipment, thermal treatment equipment (primary chamber, blowers, air pollution control equipment). Equipment specifications identifying manufacturer and model number, materials of construction, interior and exterior dimensions, design limitations, and normal operating conditions. Operating capacity and operating conditions for subsystem equipment; pumps, valves and other in-line devices; sizes of conveying and/or feeding devices; size and number of parallel components or lines.

Instrumentation and Controls; GA.

Detailed manufacturer's data on the overall controls, sequence of control, description of components, wiring diagrams, logic diagrams, control panel layouts, legends and standard symbols, sensors, process controllers, control operators, valves, alarms, interlocks and contaminated material feed cut-off systems. Data describing in detail the equipment used to monitor stack emissions, including the stack sampling probe, filters, gas transport tubing, sampling pump, moisture removal system, analyzer's calibration system, and data recorder.

Air Emissions and Noise Pollution Control; [_____].

An analysis of the amount of noise generated at a distance of 30 meters (100 feet) for the following octave band frequencies: 31.5, 63, 125, 250, 500, 1000, 2000, 4000, and 8000 hertz.

Redundancies; [_____].

Backup and redundancy analysis containing a failure mode analysis and an emergency manual that indicates responses to be taken under the following circumstances: (1) sudden loss of integrity of refractory lining, (2) puffing or sudden occurrence of fugitive emissions, (3) failure of temperature monitoring control mechanism, (4) primary burner and/or air port clogging or failure, (5) electrical power failure (primary or secondary), (6) scrubber water flow or scrubber water makeup flow out of range, (7) excessive solids deposition in the air pollution control system, (8) loss of quench water, (9) increase in gas temperature after quench zone and (10) demister operation failure.

SD-04 Drawings

Layout; GA.

Drawings showing dimensions of the equipment, layout of the thermal desorption system and subsystems, including location of components and onsite improvements. Drawings showing dimensions, layout, location of barriers, capacities, and placement of the stockpiles. Drawings shall be to the approved scale.

Detailed Process Flow Diagram; GA.

Flow diagram for process equipment associated with the thermal desorption system and data including but not limited to: contaminated material stream flows; direction of material flow, including range of flowrate and range of composition, identified by lines and arrows denoting the direction and destination of the flow; material, mass and energy balances for the entire thermal desorption system.

Piping and Instrumentation Diagram; GA.

Piping and instrumentation diagram indicating: process equipment; instrumentation; piping and valves; stacks, vents and dampers; control equipment (including sensors, process controllers, control operators, valves, interlocks, alarms, and contaminated material feed cut-off systems); labels and other necessary information to correlate to the process flow diagram.

SD-09 Reports

Test Results; [_____].

Reports of inspections or tests, including analysis and interpretation of test results. Each report shall be properly identified. Test methods used shall be identified and test results shall be recorded.

Startup; GA.

Reports containing the results of startup and proof of performance. The reports shall contain the information necessary for making application for an operating permit.

SD-18 Records

Logs; [_____].

An operating record as described in this specification. Inspection and maintenance checklists and records of preventive maintenance and repairs.

Software Packages; FIO.

Instructions for use of software packages necessary to evaluate the operating data from the control system and daily operating data on magnetic media.

1.4 REGULATORY REQUIREMENTS

****
NOTE: The designer should determine state, regional, or local noise abatement requirements. Requirements may vary on 24-hour or weekly cycles.
****

1.4.1 Air Emissions and Noise Pollution Control

The thermal desorption system shall conform to applicable state, regional, and local regulations regarding ambient air emissions and noise pollution control. A noise analysis predicting the amount of noise generated by the system shall be furnished prior to mobilization. Maximum approved noise levels shall not be exceeded.

1.4.2 Hazardous Materials

If any process residuals are found to contain hazardous materials, they shall be transported and disposed of in accordance with Section 02120 Transportation and Disposal of Hazardous Materials.

1.5 SITE-SPECIFIC TREATABILITY STUDIES

****

NOTE: Coordinate list of applicable treatability studies. Treatability studies performed on the materials should be documented in this paragraph or furnished as an attachment to this section of the specifications. Summarize the results in this paragraph.

****

1.6 ENVIRONMENTAL REQUIREMENTS

****

NOTE: Include site and soil characterization data and reference other sections that contain the data.

****

1.6.1 Existing Conditions

Generalized characteristics and location of the contaminated materials are as indicated on the drawings and described in Sections [_____] [_____].

1.6.2 Field Measurements

****

NOTE: The unit price for thermal desorption should be based on in situ volume. For liquids and sludges the unit of measure should be mass. Materials requiring retreatment should be segregated from treated materials.

****

The amount of material to be treated shall be verified by [in-place measurement] [mass]. The quantity of materials requiring retreatment shall be reported and subtracted from the daily production when calculating treatment costs.

1.6.3 Erection

Erection and/or installation shall be performed with minimal damage to the existing site environment. Welding shall be performed in accordance with AWS D1.1 by welders certified to have passed qualification tests using procedures covered in AWS B2.1 or ASME BPV IX. The Contractor shall require any welder to retake the test when, in the opinion of the Contracting Officer, the work creates reasonable doubt as to the welder's proficiency.

1.7 SEQUENCING AND SCHEDULING

****
NOTE: Verify that objectives have been identified in PART 3.
****

Documentation of successful accomplishment of the objectives of each phase of operation is required prior to approval to begin the next phase of operations.

1.7.1 Mobilization Plan

Permits and permit equivalents shall be obtained prior to mobilization. Mobilization shall include transportation of the equipment to the site, equipment erection and installation, but not operation. Mobilization shall not commence until approval of the mobilization plan is received from the Contracting Officer.

1.7.2 Proof of Performance

Proof of performance shall be in accordance with the approved Proof of Performance Plan.

1.8 INSTRUMENTATION AND CONTROLS

Continuous emission monitors shall be in accordance with the appropriate Performance Specifications and EPA 450/4-80/023R. Systems shall be adequately protected from damage from on-site activity.

1.8.1 Control Room

****
NOTE: The designer should consult the military installation regarding the usage of radio communications. Closed-circuit TV requirements should be deleted if provided by another section.
****

A fully enclosed control room provided with system controls, instrument readouts, and data recording devices shall be maintained. The control room shall be heated and air conditioned, permitting year round occupancy, and shall meet instrumentation and control equipment manufacturer's operating specifications. If the control room is located in the exclusion zone, provision shall be made for personnel using protective clothing and equipment. If the control room is located in the support zone, a hard wired intercommunication system and two hard wire telephonic communication channels between the control room and thermal desorption system operating

area shall be provided to allow control room operators to communicate with system operators. Closed circuit television monitoring of operations shall be provided in the control room.

1.8.2 Redundancies

Fully redundant backup capability within each subsystem to safely terminate system operations at the control room and at the thermal desorption system shall be provided. Duplexing or redundancies within the instrumentation and control systems shall be adequate to provide uninterrupted continuous monitoring of the emissions and to demonstrate operation in accordance with the approved operating conditions.

1.8.3 Displays and Data

Monitored parameters and excursion alarms shall be displayed locally and displayed and recorded in the control room. Process and emissions data shall be maintained in the control room and recorded on magnetic media in the approved microcomputer compatible digital format. Flow information shall include rate monitoring, integration, and totalizing. Hard copies of recorded data and summaries of recorded data shall be maintained in the control room. The copies shall be available upon request.

1.8.4 Instrumentation, Sensors, Recorders, and Sampling

****

NOTE: 40 CFR Part 761 Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions applies when the contaminated material to be treated contains PCBs in excess of 50 mg/kg. Emissions monitoring and rates from 40 CFR Part 264, Subpart O may apply in the absence of state regulations. Contact the appropriate federal and state regulatory agencies to determine the extent of monitoring required.

****

1.8.4.1 Instrumentation

Instrumentation and equipment including sensors, local indicators, connecting devices, recorders, analyzers and components necessary to monitor and control the safe and efficient operation of the system shall be provided.

1.8.4.2 Stack Emissions Monitoring and Sampling

Continuous monitoring with calibration/verification sampling shall be provided as shown in TABLE 2. Digital data shall be recorded at intervals not exceeding 1 minute. Calibration of sensors shall be with standards traceable to NIST and in conformance with NIST SP 250.

TABLE 2

STACK EMISSIONS MONITORING AND SAMPLING SCHEDULE

Operating Period	Parameter	Frequency
[Proof of Performance]	oxygen	[continuous] [_____]
[interim operations]		[_____] [not required]
[operations]		[_____] [not required]
[Proof of Performance]	carbon monoxide	[continuous] [_____]
[interim operations]		[_____] [not required]
[operations]		[_____] [not required]
[Proof of Performance]	carbon dioxide	[continuous] [_____]
[interim operations]		[_____] [not required]
[operations]		[_____] [not required]
[Proof of Performance]	total hydrocarbon (HC)	[continuous] [_____]
[interim operations]		[_____] [not required]
[operation]		[_____] [not required]
[Proof of Performance]	principal organic	[in accordance with Proof of Performance Plan] [_____]
[interim operations]		[_____] [not required]
[operation]		[_____] [not required]
[Proof of Performance]	products of incomplete combustion (PICs)	[in accordance with Proof of Performance Plan] [_____]
[interim operations]		[_____] [not required]
[operation]		[_____] [not required]
[Proof of Performance]	opacity	[weekly] [daily] [_____]
[interim operations]		[_____] [not required]
[operations]		[_____] [not required]

[Proof of Performance] particulates
[in accordance with Proof of Performance Plan] [_____]
[interim operations] [_____] [not required]
[operations] [_____] [not required]

[Proof of Performance] metals
[in accordance with Proof of Performance Plan] [_____]
[interim operations] [_____] [not required]
[operations] [_____] [not required]

1.8.5 Sampling

Stack sampling port and equipment for collecting discrete and composite samples shall be provided with adequate access for personnel and equipment.

1.8.6 Interlocks and Alarms

1.8.6.1 Visible Alarms

Visible alarms shall consist of lights on the main control panel, flashing symbols on the screen of the microprocessor controller in the control room, and, for each interlock that stops the contaminated material feed system, lights at the equipment location.

1.8.6.2 Audible Alarms

Audible alarm activation shall be provided for each interlock that stops the feed to the thermal processing unit.

1.8.6.3 Remote Alarms

****
NOTE: In cases in which remote alarms are not required, this paragraph should be deleted. In cases in which it will be desirable to have immediate notification of off-site persons, this paragraph should be included. Persons to be called and the order of calling should be specified. The Contracting Officer or a designated representative should always be included in the calling sequence.
****

Auto dialing to the indicated remote locations shall be provided for each interlock that stops the contaminated material feed to the thermal processing unit. The calling sequence shall be is [_____], [_____] then [_____] in priority order.

1.8.7 Electrical Work

All electrical work, wiring, and controls shall conform to the applicable requirements of NFPA 70.

1.8.8 Thermometers

ASME PTC 19.3, with wells and temperature range suitable for the use encountered.

1.8.9 Draft Gauges

Gauges shall conform to ASME B40.1 with a diaphragm or bellows actuating system and a circular scale. The gauges shall have a zero adjustment screw. Suitable shutoff cocks shall be provided.

1.8.10 Pressure Gauges

Gauges shall conform to ASME B40.1 and be of pressure-detecting class, single Bourdon tube style, and suitable for detecting air pressure.

1.8.11 Thermocouples

Sensors shall conform to ISA MC96.1, Type K, and shall be provided in the combustion chamber or as otherwise directed. The thermocouple shall be suitable for continuous operation and control at temperatures up to [1540] [_____] degrees C, ([2800] [_____] degrees F,) accurate to 0.75%, and shall be long enough to be inserted 150 mm (6 inches) into the furnace. The thermocouple shall be provided with an adjustable flange and with a high-temperature metal alloy, closed-end, protecting tube suitable for insertion into the furnace without support of the projecting end. Compensating lead wire 1.52 mm (16 gauge) (16 gauge) in diameter and 30 m (100 feet) long with a weatherproof braid shall be supplied for connecting the thermocouple to the instrument. The installed unit shall indicate gas passage temperatures and shall control burner operation.

1.9 CONTAMINATED MATERIAL FEED SYSTEM

1.9.1 Support Equipment

****
NOTE: The designer needs to address rocks, construction debris, trees, stumps, drums, barrels, etc., and oversize materials. Oversize materials are any materials too large to be compatible with the thermal desorber. Materials may be required to be shredded and treated or separated from the feed material, decontaminated, and disposed on or off site. Maximum allowable sizes to be treated in the thermal desorber should be specified.
****

Material handling and contaminated material feed systems provided shall be capable of [shredding], [conveying], [pumping], [and] [screw feeding] of contaminated materials, separately or in combination, to the primary chamber. Pretreatment shall include crushing or grinding and screening as required to produce material no larger than [_____] mm ([_____] inch) in diameter and which is otherwise compatible with the thermal desorber.

1.9.2 Capacity

Capacity of the contaminated material feed system shall be consistent with the capacity of the thermal desorption system.

1.9.3 Metering

The contaminated material feed system shall be capable of weighing the contaminated materials (liquid and solid) introduced into the thermal desorption system with an accuracy of plus or minus 2% of true weight.

1.9.4 Conveyors

****
NOTE: The designer should make a determination of the maximum contaminated material feed rate which could be sustained without releasing VOCs to the air in violation of air quality regulations. This determination should be made using feed rates and contaminant concentrations typical of full-scale production. If the potential does not exist for the release of unacceptable amounts of VOCs, this paragraph may be deleted. Calculations supporting this determination should be included in the Design Analysis.
****

Contaminated material feed conveyors shall be covered and vented to the air pollution control system.

1.10 TREATED MATERIAL AND RESIDUES

Equipment and storage facilities shall be provided for removing, handling, and storing residues resulting from thermal treatment, including treated material and solids captured by the pollution control system.

1.10.1 Capacity

Capacity for treated material and solids captured by the pollution control system removal, handling, and storage systems shall be consistent with the capacity of the thermal desorption system.

1.10.2 Segregation of Materials

****
NOTE: Thermal desorption is a separation process. Combining the air pollution control residuals with the treated materials may make the treated material fail backfill requirements for metals leachability. Regulations generally allow combining prior to testing.
****

Separate storage for treated material and solids captured by the pollution control system handling systems shall be adequate for segregating a minimum of [72] [_____] hours production to allow for results from sampling and analyses prior to additional treatment or disposal.

1.10.3 Rehydration

****
NOTE: Final moisture content may be specified here, if appropriate.
****

Treated material handling systems shall include provisions for rehydration, prior to storage, of material leaving the thermal desorption system in order to reduce the fugitive emissions and to confine the materials to the proper storage area.

1.11 AIR SUPPLY AND POLLUTION CONTROL SYSTEMS

1.11.1 Air Supply

A forced draft (FD) blower/fan or fans shall be used to provide combustion air for the burners.

1.11.2 Induced Draft (ID) Fan

The induced draft (ID) blower/fan or fans shall be used to maintain negative pressure throughout the system.

1.11.3 Fugitive Emissions Control

Emissions from the combustion zone shall be controlled by keeping the combustion zone sealed and maintaining a combustion zone pressure lower than atmospheric pressure. Alternative means that have been demonstrated to provide equivalent fugitive emissions control may be implemented with the approval of the Contracting Officer.

1.11.4 Quench

Off-gases from the primary soil treatment zone shall be cooled to temperatures protective of downstream units and equipment.

1.11.5 Stack Emissions Control

****
NOTE: Indicate design wind force the stack will have to withstand. Structural design should also include seismic resistance, when appropriate.
****

The air pollution control system shall be capable of controlling gaseous, solid, and aerosol-type emissions to meet the performance requirements. Stack support shall be in accordance with NFPA 82 and NFPA 211, as applicable. Vertical and lateral supports for exterior chimneys shall withstand wind forces of [_____] km/hour. ([_____] mph.)

1.11.6 Water and Liquid Waste

The air pollution control system shall be designed to minimize water consumption and liquid waste generation. Liquids in the air pollution control system shall be recirculated to the maximum extent practicable prior to wasting to the liquid waste system.

1.12 PROCESS RESIDUALS

****
NOTE: Verify that all process residual streams are covered.
****

1.12.1 Liquid Wastes

Residual liquid wastes from the air pollution control system and liquids collected from the [air pollution control system] [stockpile] [____] shall be sampled, treated, and disposed of in accordance with regulatory and contract requirements.

1.12.2 Solids

Residual solid materials from the [air pollution control system] [liquid waste treatment system] [____] shall be sampled, treated, and disposed of in accordance with regulatory and contract requirements.

1.13 AUXILIARY FUEL SYSTEM

1.13.1 Feed Capability

The auxiliary fuel system shall have direct-feed capability to the thermal destruction system. Meters, pressure gauges, and controls shall be provided to maintain proper operating conditions. Design shall be in conformance with the applicable requirements of NFPA 30 and NFPA 31, NFPA 54, or NFPA 58, as appropriate to the fuel type.

1.13.2 Secondary Containment

Auxiliary fuel storage tanks shall be provided with secondary containment as required by paragraph 2-3.4 Control of Spillage from Aboveground Tanks of NFPA 30.

PART 2 PRODUCTS (Not Applicable)

PART 3 EXECUTION

3.1 LAYOUT

****
NOTE: Coordinate the drawings to allow the best access possible to the work area.
****

The size of the process area shall not be increased without approval of the Contracting Officer. Costs associated with any area increase shall be borne by the Contractor, including costs of construction, demolition, and site restoration.

3.1.1 Equipment

The area indicated on the drawings shall be used for equipment such as an auxiliary generator; dewatering equipment; pretreatment equipment such as shredders, screens, etc.; air emission controls and monitoring equipment; contaminated material conveyance, preparation and loading equipment; and fuel tanks.

3.1.2 Stockpiles

The area provided for stockpiling shall be used for segregated temporary storage of untreated contaminated materials, treated materials, and solids captured by the pollution control system. Contaminated materials, treated materials and solids captured by the pollution control system shall not be mixed. Facilities for treated materials and solids captured by the pollution control system shall maintain segregation of treated materials and solids captured by the pollution control system until each has been characterized for additional treatment and/or disposal. Stockpiles shall be constructed to include:

a. A chemical-resistant impermeable geomembrane liner with a minimum thickness of 1.0 mm (40 mils). Subgrade preparation; and installation, testing, inspection, and protection of the liner shall be in accordance with SECTION 02271 WASTE CONTAINMENT GEOMEMBRANE.

b. An impermeable geomembrane cover with a minimum thickness of 0.25 mm (10 mils) to prevent precipitation from entering the stockpile.

c. Berms surrounding the stockpile which are a minimum of 0.9 m (1 foot) in height.

d. The liner shall be sloped to a low point to allow leachate to be collected. Leachate collected from the stockpile shall be handled in accordance with paragraph Liquid Wastes. Leachate collected from the stockpile may be used in the thermal desorption process provided the treated material meets the physical and chemical post-treatment test criteria.

3.1.3 Fuel System

Fuel system installation and testing shall comply with the applicable requirements of NFPA 30 and NFPA 31, NFPA 54, or NFPA 58, as appropriate to the type of fuel.

3.2 INSTALLATION/ERECTION/REMOVAL

The installation/erection of the thermal desorption system shall be performed to allow removal of the system from the site and site restoration.

3.3 SAMPLING, MONITORING, AND INSPECTIONS

****

NOTE: Verify that the contract documents cover the sample preservation and analytical method for contaminated and treated materials, stack emissions for parameters required in paragraph Stack Emissions Monitoring and Sampling, and solids captured by the pollution control system. Reference should be made to 40 CFR Part 266 for the analysis for TCLP metals.

Sampling requirements are project specific. Sampling frequency requirements and composite sampling techniques are negotiated with the regulatory agency.

Typically, treated materials from each day are stockpiled separately. Therefore, testing is normally done on a daily basis with varying composite sampling requirements.

****

Sample preservation and analytical methods are covered in Section 01450 CHEMICAL DATA QUALITY CONTROL. Contaminated material feed, treated material, and solids captured by the air pollution control system shall be sampled and analyzed as allowed by the permits and as specified. The sampling of treated soils and solids captured by the air pollution control system shall be in accordance with ASTM E 122.

3.3.1 Minimum Sampling

Sampling and analyses shall be performed in accordance with the schedule as shown in TABLE 3.

TABLE 3

MATERIAL SAMPLING FREQUENCY REQUIREMENTS

COMPONENT	MATERIAL		
	CONTAMINATED	TREATED	SOLIDS CAPTURED BY THE POLLUTION CONTROL SYSTEM
volatile organics	[_____]	[_____]	[_____]
semivolatile organics	[_____]	[_____]	[_____]
polychlorinated biphenyls (PCBs)	[_____]	[_____]	[_____]
TCLP metals	[NA]	[daily]	[_____]
metals	[NA]	[daily]	[_____]

3.3.2 Stack Sampling

Stack samples shall be taken in accordance with state regulation.

3.3.3 Visual Inspections

The thermal desorber and associated equipment (pumps, valves, conveyors, pipes, etc.) shall be subjected to thorough visual inspections for leaks, spills, fugitive emissions, and signs of tampering or mechanical failure as indicated in TABLE 4.

TABLE 4

VISUAL INSPECTION SCHEDULE

Phase of Operation	Minimum Inspection Frequency
Proof of Performance	[Once per 8-hour shift] [Daily]
Interim Operations	[Once per 8-hour shift] [Daily]
Operations	[Daily] [Weekly]

3.3.4 Interlocks, Automatic Cut-Offs, and Alarms

Interlocks, automatic contaminated material feed cut-off and associated alarms shall be tested at least [weekly] [_____].

3.4 LOGS

Data from sampling, inspections, and tests shall be recorded and the records placed in the operating log. The field logbook shall describe calibration procedures conducted and results obtained. Logs shall be maintained throughout the duration of operations and shall be made available for inspection upon request by the Contracting Officer.

3.5 STARTUP

Startup shall include material-handling systems demonstration, instrumentation calibration, control interlock demonstration, and 24 hour operation. Startup operations shall demonstrate that the system is capable of processing material at the proposed feed rate and that the air pollution control system is capable of attaining the required throughput rates. Startup activities shall be performed using uncontaminated material.

3.5.1 Startup Plan

The Contractor shall submit a startup plan. The plan shall describe control system functions and specific procedures proposed to demonstrate each function and for testing the system with uncontaminated materials; formats and procedures for reporting the material-handling demonstration and hot check results; and proposed operating procedures for the proof of performance with detailed descriptions of the sampling and analysis to be performed.

3.5.2 Systems Demonstration

The Contractor shall demonstrate the contaminated material preparation and feed systems and the treated material and solids captured by the pollution control system handling systems. The systems demonstration shall not commence until written approval is received from the Contracting Officer. The systems and the treated material and solids captured by the pollution control system handling systems shall operate continuously at the proposed maximum feed rate for 4 hours without a malfunction or shutdown related to the systems. The systems demonstration shall be conducted using uncontaminated material. There shall be no fugitive emissions, or "dusting".

3.5.3 Instrumentation Calibration

Instrumentation calibration shall ensure that compliance-related instrumentation functions will be performed reliably and accurately. Test instruments shall be calibrated by a recognized standards laboratory 30 days prior to testing with standards traceable to NIST SP 250. Instrumentation and control system calibrations will be witnessed by the Contracting Officer.

3.5.4 Control Interlock Demonstration

Following instrumentation calibration, it shall be demonstrated that control system interlocks and alarms are programmed correctly and are fully functional. Each alarm point shall be tested for proper response. Alarms, interlocks, and emergency responses (activation of combustion gas by-pass system or an emergency system shut down) shall be demonstrated. Operating conditions which trigger system alarms may be artificially induced in the field, or the control set points may be altered to invoke the desired response alarm. Appropriate control system responses (including interlocks, alarms, by-pass activation, and/or emergency shutdowns) to each of the specified stimuli shall be demonstrated.

3.5.5 24-Hour Operation

The system shall be placed in operation under conditions proposed in the Proof of Performance Plan for 24-hours or the treatment of one batch (if a batch system) without a malfunction or shutdown related to the contaminated material feed or the treated material and solids captured by the pollution control system handling systems with all continuous emissions monitoring systems functional throughout the 24-hour operations. Shakedown shall begin after the 24-hour prove-out period. Shakedown may be performed on contaminated materials.

3.5.6 Reporting

An interim letter report will be acceptable with the results formally reported in the startup report.

3.6 PROOF OF PERFORMANCE PLAN

****

NOTE: D elete this paragraph when treating POL-contaminated soils (nonhazardous waste). The system should not be approved for operation until acceptable removal and other operating parameters are successfully achieved during the Proof of Performance. Production operating conditions should be established from the Proof of Performance results.

Approved production operating conditions should become contract requirements.

If acceptable removal and other operating parameters are not achieved, production operations should not be approved. Results of the Proof of Performance should be analyzed and the causes of deficiencies evaluated. The Contractor should be required to make physical and operational changes to the thermal desorption system to bring it into compliance with the required operating parameters and removal efficiencies.

If the first attempt at performing a Proof of Performance fails, each subsequent attempt should include a separate Proof of Performance report. Second and third proofs of performance, if needed, should be performed at no extra cost to the Government.

Upon completion of a successful Proof of Performance, the thermal desorption system should be approved for production operations contingent on the specified operating conditions established from the successful Proof of Performance test results.

After failure of the third Proof of Performance attempt and/or expiration of 1 calendar year from the initiation of Proof of Performance operations, the Contractor may be considered in default in accordance with the Contract Clauses.

A complete Proof of Performance, regardless of similarities between treatment trains, should be conducted on each treatment train of multiple secondary treatment trains or air pollution control trains that are used with a single thermal desorption unit. Each train should be tested simultaneously to the maximum practical extent. For multiple treatment trains that will be operated under different operating conditions or different contaminated material feed rates, each proposed set of conditions should be demonstrated during the Proof of Performance.

The designer should ensure that regulators define permitting process and time delays associated with the review and approval process. Interim conditions should be adamantly sought as the permit process could delay construction operations and greatly increase cost of project.

An interim operating period should commence within 7 calendar days after receipt of the Proof of Performance test results and the issuance of interim operating conditions. The interim operating period should continue for the total number of calendar days remaining in the period of time allowed for preparation and submittal of the Proof of Performance report and the number of calendar days allowed for review and approval. Loss of potential

interim operating time resulting from delays in submittal of an acceptable Proof of Performance report should be the responsibility of the Contractor. The interim operating approval should expire at the end of the period described above operation should cease until a final production operation approval is issued. Operating conditions during the interim operating period should be determined based on performance data obtained during Proof of Performance operations. At a minimum, these conditions should include:

a. Total mass feed should be based on the feed rate demonstrated to meet treated material quality standards during preproduction operations.

b. Desorber operating conditions should demonstrate the ability to meet treatment standards during preproduction operations.

c. Air pollution control system operating conditions should be demonstrated during the Proof of Performance to ensure compliance with all emissions standards.

d. Sampling and analysis requirements of treated materials should be in accordance with the Sampling and Analysis Plan.

****

The Contractor shall submit a Proof of Performance Plan. Proof of performance shall be conducted in accordance with the approved Proof of Performance Plan.

3.6.1 Schedule

Written notification of the anticipated date of the full proof of performance shall be received at least 7 days prior to the projected start date. Proof of performance operations may begin upon receipt of written approval of the Proof of Performance Plan and written notification that final shakedown activities have been completed and that all systems are ready to conduct a full proof of performance.

3.6.2 Source of Material

****

NOTE: Specify the locations and depths at which samples for the field demonstration will be obtained. Chemical testing should be performed to verify that the materials to be used for the field demonstration contain the contaminants of concern at high enough concentrations to test the process. Additional testing may be warranted to verify that the physical properties of the materials are appropriate for backfilling.

****

Contaminated material used for the field demonstration shall be obtained from [_____]. Prior to performing the field demonstration, contaminated material to be used for the field demonstration shall be tested to verify it contains the following minimum levels of contamination: [_____].

3.6.3 Operating Conditions

All systems shall be operated at the conditions specified in the Proof of Performance Plan for the duration of the proof of performance.

3.6.4 Field Proof of Performance Report

The proof of performance report shall include results of the proof of performance, including sample analysis data, calculations, and conclusions within [7] [14] [_____] days of the completion of a proof of performance. At a minimum, data collected during each proof of performance shall be sufficient to make the following determinations:

3.6.4.1 Quantitative Analysis of the Materials

A quantitative analysis of each contaminated feed, treated material, and pollution control system stream for each individual run for each parameter stated in the Proof of Performance Plan. From each feed stream, analysis of composites made from grab samples taken at 15-minute intervals for each individual test run during the proof of performance. The quantitative analysis shall include analyses for any surrogate or spiking compounds.

3.6.4.2 Quantitative Analysis of the Stack Gases

A quantitative analysis shall be made of the stack exhaust gases for the concentration and mass emissions of O_2, [CO_2,] CO, [HCl,] [NOx,] [SO_2,] [THC,] [metals] and particulates for the proof of performance. The stack gas velocity and the concentration of O_2, [CO_2,] CO, HCl, [NOx,] [SO_2,] [and] [THC] in the stack exhaust gases shall be continuously measured and recorded.

3.6.4.3 Material and Energy Balances

****

NOTE: If the contaminated material characterization data showed negligible chloride content, delete the HCl requirement.

****

A computation of the mass emission rate of particulates, in accordance with 40 CFR Part 264, Subpart O. If the HCl emission rate exceeds 1.8 kg, (4 pounds,) of HCl per hour, a computation of the HCl removal efficiency in accordance with 40 CFR Part 264, Subpart O shall be performed.

3.6.4.4 Fugitive Emissions

Identification of sources of fugitive emissions and means of control of the emissions.

3.6.4.5 Continuous Measurement and Recording

Continuous measurement and recording of operating parameters as required in the approved Proof of Performance Plan.

3.6.4.6 Other Requirements

Other monitoring, sampling, and/or analyses required by the approved Proof of Performance Plan.

3.7 UTILITIES

****

NOTE: The system utilities requirements should be identified in the Contractor's design. The following information may be used as a check: the amount required for a 12,000 - 18,000 kg (15 – 20 ton) per hour unit is 5 - 35 L per second (75 – 600 gpm) of water, 1200 - 2500 kW of electricity and 30 - 60 cubic meters per minute (1000 - 2000 scfm) of natural gas. The Contractor should verify the adequacy of the existing utilities and be responsible for the required agreements with the utility companies for usage and any required changes.

Points of connection are normally shown on the drawings. Occasionally names, addresses, and telephone numbers of the utility companies are shown on the drawings. Delete the following paragraphs if the information is shown elsewhere.

****

Fuel and utilities shall be provided at locations indicated. Contractor shall verify availability and locations of utilities and shall compensate the utility company for connection and usage.

3.7.1 Electricity

The power [utility] [company] is [_____], phone number [_____].

3.7.2 Water

The water [utility] [company] is [_____], phone number [_____].

3.7.3 Natural Gas

The natural gas [utility] [company] is [_____], phone number [_____].

3.8 DEMOBILIZATION PLAN

Demobilization shall be completed in accordance with the approved demobilization plan. Demobilization period shall begin after the contaminated materials have been treated to the requirements of this section. Demobilization shall include disconnection of utilities, decontamination, disassembly, and removal of thermal desorption system equipment, materials-handling equipment, structures, and concrete pads related to the thermal desorption system. Demobilization shall be considered complete when the thermal desorption equipment and related equipment have left the site and the equipment and stockpile areas have been restored.

- End of Section --

APPENDIX I

ACRONYMS AND ABBREVIATIONS

USED IN APPLICATION GUIDE TEXT AND APPENDICES

ACRONYMS AND ABBREVIATIONS

API	American Petroleum Institute
ARAR	applicable or relevant and appropriate requirements
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BADCAT	Bay Area Defense Conversion Action Team
BAFO	best and final offer
bgs	below grade surface
BRAC	base realignment and closure
BTEX	benzene, toluene, ethylbenzene, and xylenes
Btu	British thermal unit
CBD	*Commerce Business Daily*
CCB	construction criteria base
CEMS	continuous emissions monitoring system
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CO	carbon monoxide
CSI	Construction Specifications Institute
CY	cubic yards
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
DRE	destruction and removal efficiency
EDC	engineering during construction
EPA	Environmental Protection Agency
ER	environmental restoration
FAR	Federal Acquisition Regulation
FAC	Florida Administrative Code
FD	forced draft
FDEP	Florida Department of Environmental Protection
FIO	for information only
FRP	fiberglass-reinforced plastic
G & A	general and administration
GA	government approved
GW	groundwater
HAVE	hot-air vapor extraction
HC	total hydrocarbon
HCI	hydrochloric acid; hydrogen chloride
HEPA	high-efficiency particulate aire

HTRW	hazardous, toxic, and radioactive waste
HTTD	high-temperature thermal desorption
HWIR	Hazardous Waste Identification Rule
I & C	instrumentation and control
ID	induced draft
ISA	International Society for Measurement and Control
JP	jet propulsion (fwd)
K_d	sorption, coefficient
K_{ow}	octanol/water partition coefficient
kwh	kilowatt-hour
LPG	liquiefied petroleum gas
LTEVF	low-temperature enhanced volatilization facility
LTTA	low-temperature thermal aeration
LUST	leaking underground storage tank
MTBE	methyl-*tert*-butyl-ether
NA	not applicable
NCP	National Contingency Plan
ND	not detected
NFESC	Naval Facilities Engineering Service Center
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NO_x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NS	Naval Station
O & M	Operation and Maintenance
OSHA	Occupational Safety and Health Act
OWTP	Oily Waste Treatment Plant
PAH	polycyclic aromatic hydrocarbon
PCB	polychorinated biphenyl
PCE	tetrachloroethene
PCS	petroleum-contaminated soil
PE	Project Engineer
PI	plasticity index
PIC	product or incomplete combustion
PM	particulate matter
POHC	principal organic hazardous waste constituent
POL	petroleum, oil, or lubricants

PPE	personal protective equipment
ppm	parts per million
ppmv	parts per million by volume
QA/QC	quality assurance/quality control
QCP	Quality Control Procedures
RA	remedial action
RBSL	risk-based screening level
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RDF	refuse-derived fuel
RFP	request for proposals
RI	remedial investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	record of decision
RPM	Remediation Project Manager
S	soil
S & A	Supervision & Administration
SB/SDB	small business/small disadvantaged business
scfm	standard cubic feet per minute
SO_2	sulfuct dioxide
SOP	standard operating procedures
SOW	statement of work
SSL	soil screening level
SSR	Southwest Soil Remediation, Inc.
STTF SOP	Soil Thermal Treatment Facilities Standard Operating Procedures
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TCA	trichloroethane
TCE	trichloroethylene, trichloroethene
TCLP	toxicity characteristic leaching procedure
TD	thermal desorption/desorber
TERC	Total Environmental Restoration Contract
THC	total hydrocarbons
tph	tons per hour
TPH	total petroleum hydrocarbon
TR	technical report
TRPH	total recoverable petroleum hydrocarbons
TSCA	Toxic Substances Control Act
TSDF	treatment, storage, or disposal facility

UOM	unit of measure
USCS	Unified Soil Classification System
U.S. EPA	U.S. Environmental Protection Agency
UST	underground storage tank
UTS	Universal Treatment Standards
VISITT	Vendor Information System for Innovative Treatment Technologies
VOA	volatile organic analysis
VOC	volatile organic compound
WBS	work breakdown structure
w/w	weight per weight